SMALLHOLDER MAIZE FARMING HOUSEHOLDS' VULNERABILITY TO CLIMATE CHANGE IN THE BRONG-AHAFO REGION OF GHANA

BY

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

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DECLARATION

I, Derick Adu Taylor, the author of this thesis titled: ***"SMALLHOLDER MAIZE FARMING HOUSEHOLDS' VULNERABILITY TO CLIMATE CHANGE IN THE BRONG-AHAFO REGION OF GHANA"***, do hereby declare that apart from the references to other people's work which I have duly acknowledged, the results presented in this thesis was done entirely by me. This work has never been presented in whole or in part for any other degree in this university or elsewhere.

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This thesis has been submitted with our approval as supervisors.

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Date:	Date: ....

DEDICATION

This thesis is dedicated first of all to God Almighty. I also dedicate it to my parents Mr. and Mrs. Mensah, my sweet siblings, Michael, Asante, Raphael, Theophilus and Maxwell for their continuous love and support.

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I am very honoured to have worked with two of the most distinguished Agricultural Economists in the country: Dr. John K.M Kuwornu and Dr. Henry Anim Somuah of the Department of Agricultural Economics and Agribusiness: University of Ghana, Legon. I cannot thank you enough for the academic guidance, patience, time and all the inputs which have helped shape this work.

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To God be the glory, great things He has done. Amen.

ABSTRACT

This study investigated smallholder maize farming households' vulnerability to climate change, factors affecting the vulnerability of the households and households' constraints to climate change adaptation strategies in the Wenchi and Techiman Municipalities in the Brong-Ahafo Region of Ghana. Primary data were collected through a personal administered questionnaire. One Hundred and fifty (150) smallholder maize farming households were randomly sampled. The Livelihood vulnerability index was employed to establish household vulnerability to climate change. The generalized least square regression model was employed to estimate the factors affecting household vulnerability, and the Kendall's ranking technique was used to rank the households' constraints to climate change adaptation strategies. The result shows that in the pooled sample, 35.3% of the households were lowly vulnerable, 38.7% were moderately vulnerable, 24.7% were highly vulnerable and only 1.3% were extremely vulnerable. In the Wenchi Municipality 40% were lowly vulnerable, 44% were moderately vulnerable, 14.7% were highly vulnerable and 1.3% were extremely vulnerable. In the Techiman Municipality 30.7% were lowly vulnerable, 33.3% were moderately vulnerable and 34.7% were highly vulnerable whiles only 1.3% were extremely vulnerable. The overall index showed that Wenchi Municipality was more vulnerable than the Techiman Municipality with Livelihood Vulnerability Indices of 0.346 and 0.312 as well as the LVI-IPCC of -0.011 and -0.015 respectively. Parameter estimates of the generalized least regression showed that for the pooled sample, gender of household head, age of head, household size, farm size, hired labour, family labour, physical asset, rainfall perception and economically active female members of household influenced household vulnerability. For the Techiman Municipality, farm size, temperature perception, hired labour, family labour, physical asset and economically active female members of household influenced household vulnerability to climate change. In the Wenchi Municipality, gender of household head, farm size, rainfall perception and family labour influenced household vulnerability to climate change. The result of the Kendall's ranking technique showed that for the pooled sample, the three most pressing constraints to climate change adaptation strategies were, lack of access to credit, lack of a ready market for produce and poor extension service with mean scores of 2.01, 2.85 and 3.48 respectively. For the Techiman Municipality the three most important constraints were, lack of access to credit, poor extension service and lack of a ready market for produce with mean scores of 2.25, 2.61 and 3.45 respectively, while in the Wenchi Municipality, lack of access to credit, lack of a ready market for produce and lack of access to meteorological information were the three most pressing constraints with mean scores of 1.77, 2.24 and 4.28 respectively. The results reveal households are vulnerable to climate change. Hence a policy regarding to health would help decrease vulnerability of households. Also rural development policy would create more employment opportunities for the households leading to improved livelihoods.

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LIST OF ACRONYMS

CCDARE	Climate Change and Development Adapting by Reducing Vulnerability
CIMMYT	International Maize and Wheat Improvement Center
EPA	Environmental Protection Agency
ETC	European Tropical Center
FAO	Food and Agriculture Organization
FARNRPAN	Food Agriculture and National Resources Policy Analysis Network
GDP	Gross Domestic Product
GLS	Generalized Least Square
GSS	Ghana Statistical Service
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
ISSER	Institute of Statistical, Social and Economic Research
LVI	Livelihood Vulnerability Index
MDGs	Millennium Development Goals
MiDA	Millennium Development Authority
MLGRD	Ministry of Local Government and Rural Development
MOFA	Ministry of Food and Agriculture
NCAP	Netherlands Climate Assistant Programme
NGOs	Non-Governmental Organizations
IISD	International Institute for Sustainable Development
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Square

PHC	Population and Housing Census
ULBI	Non-Legal Binding Instruments
UNDP	United Nation Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on forest

CHAPTER ONE

INTRODUCTION

1.1 Background

According to Scholze *et al.* (2006), adverse effect of climate change and variability has become environmental and socio-economic pest which is increasingly causing harm to people around the world. This assertion was also supported by Zhu & Zhou (2010) suggesting that climate change is now one of the main environmental problem which is threatening the survival and the development of human beings.

According to Scholze *et al.* (2006), climate change serves as a serious inhibitor to the attainment of food security and also to the fulfillment of major developmental agenda in majority of the global economies of which Ghana cannot be exempted. It has attracted the attention of the academic community, governmental and non-governmental organizations.

IPCC (2014) posits that climate change is any change in climate over a period of time which comes about as a result of both human activity and natural variability. Montle & Teweldemedhin (2014) noted that negative impact of climate change is projected to be experienced considerably by poor people who depend on semi-subsistence agriculture for their existence. The reason can be found Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) (2011), which reports that higher a proportion of the rural households are limited by the essential ability to adapt to the adverse effects of climate change. This is due to the fact that policy response is inadequate, institutional arrangements are very feeble, and interventions are not based on the needs of the households. Minia (2004) predicted that the total annual rainfall will decline by 9-27%

whiles the mean daily temperatures will rise by 2.5℃ – 3.2℃ in the whole universe by the year 2100.

The latest report by the IPCC, indicates that the adverse effects of global warming are already being experienced in every continent on the globe. However, few countries are prepared for the risk that the change conveys (IPCC, 2014). Boko *et al.* (2007) reports that agricultural production as well as food security in many African regions and countries have the highest probability to be severely compromised by climate change and variability. Orindi & Murray (2005) also noted that negative impact of climate change has been observed in Africa where it has directly affected climate-dependent activities such as agriculture and indirectly impacted on social aspects such as health, education, conflict and poverty.

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), Africa has already experienced worsening food production which has frustrated the efforts to meet the United Nations Millennium Development Goals (MDGs) of reducing hunger by half by 2015.

According to Parry (2007), poor and excessive precipitation has reduced global food crop production by 30%. This has led to an increment in food insecure households from 160 million in 1996 to over a 200 million in the 2000s. According to the World Bank (2008), climate variability and change has been experienced in Ghana with three major physical impacts observed, namely changes in rainfall and temperature as well as rise in sea level.

Lobell *et al.* (2011) reported that under optimum rain-fed management, maize-growing regions in Africa could be hit by yield losses to about 65% at 1^0C increase in temperature. Under drought conditions, 100% of these regions would experience substantial yield losses. Owusu *et al*. (2008) reports that there has been a fluctuation in the rainfall pattern in Ghana towards a longer dry season and vanishing short dry spell. High temperatures in Ghana have resulted in low yield of maize due to the reduction in growing period and increase in evapotranspiration rate (Dazé, 2007).

Agriculture contributes significantly to the Ghanaian economy. For instance, in the year 2013 according to (ISSER, 2014), agriculture contributed 22% to the nation's Gross Domestic Product (GDP). In addition, approximately two-thirds of the manufacturing value- added is based on agricultural raw materials and provide employment to about 56 percent of the work force (FAO, 2010).

To combat the global food insecurity, Borlaug (2007) made an assertion that agriculture must provide for an additional 3.5 billion people for the next five decades. He stated emphatically that the production of the three main cereal crops alone (maize, wheat and rice) will need to increase by 70 % by 2050 in order to feed the world's growing rural and urban populations.

Maize is among the world's leading crops cultivated over an area of 142 million hectares with a production of 637 million tons (Paudel *et al.*, 2009). It is one of the important staple food crops in most Sub-Saharan Africa countries. It plays key role in food security and generating income for most farmers (Hassan, 1998).

Maize is Ghana's number one staple food crop followed by rice and domestic demand for these staples is increasing. According to MiDA (2009), the domestic demand for maize is projected to grow at 2.6% annually between 2010 and 2015. However, the 21st century has seen a shortage in the per capita global food production by 7%, the shortage is believed to have being caused by climate change and variability and low soil productivity (Rosenzweig & Parry, 1994).

Morton (2007) reports that some of the most significant negative impacts of climate change in developing countries will be felt by the smallholder farming households. According to (GSS, 2008), smallholder farming households dominate in the agriculture sector in the Ghanaian economy with about 90 percent being resource poor. Smallholder farmers primarily depend on family labour and also operate under rain-fed conditions (Chamberlin, 2008). This has contributed to the inability of Ghana to produce more maize to feed its people leading to average shortfalls of 12% in domestic supply (MiDA, 2009).

In the Brong-Ahafo Region, farmers are predominantly smallholders usually involved in the cultivation of staple crops including yam, maize, cassava, cowpea and groundnut. Farmers also engage in the rearing of small ruminants such as sheep and goats (MOFA, 2011). The adverse effects of climate change and variability on crop growing and animal rearing cannot therefore be overstated.

1.2 Problem Statement

According Adger *et al.* (2013), climate change is one of the major challenges of the 21st century. Its effect is being felt in every endeavor of human life, such as biodiversity and forest ecosystems, wetlands, and coral reefs, as well as agricultural and fishery ecosystems. Its negative impact is significantly felt by the rural poor in developing countries. Chang (2009) proposes that the changes in climatic variables such as amount of rainfall, temperature, wind speed, relative humidity, sunshine duration just to mention a few are very crucial in determining the yields of crops especially maize.

Variations in climate have been described as a new security threat for Africa especially in terms of food production. This is attributed to the fact that agriculture activities are climate dependent and it is the main source of livelihood for the majority of households (FAO, 2009).

The IPCC predicts that climate change will lead to decreasing crop yields in most tropical and sub-tropical regions due to deviations in temperature and precipitation patterns (IPCC, 2007). This will have significant impact on the agricultural sectors and results to increase in the prevalence of famine in developing countries (McCarthy, 2001).

Schipper and Pelling (2006) report that a fluctuation in climate will multiply the number of smallholder households who are already vulnerable. This is due to poverty, sensitivity of their geographical locations, high dependence on natural resources and inability to adopt new livelihood strategies. Smallholder farming households are particularly vulnerable given their marginalized standing and dependence on climate-sensitive livelihood strategies.

It is asserted that poor people in the poorest countries are the most vulnerable to the impacts of climate change (Stern, 2007). Smallholder farming households have some level of experience and local knowledge in handling climate change, which help them to cope during difficult periods. However, intense and sustained levels of variability associated with long-term climate change are outside the sphere of what traditional coping strategies are able to manage (Pettengell, 2010).

Models and information about climate variability and change are only available at global, national, and continental levels. Models are not yet able to forecast the impacts at very small scales, hence extension officers face challenges in providing farmers with knowledge that is location and ecologically specific.

Without suitable policies or adaptive measures in place, the smallholder farming households will find it difficult to undertake sustainable crop production and rearing of animals in an environment with erratic climatic conditions (Nelson *et al.*, 2007).

Past studies on vulnerability in Ghana have mostly been based on poverty (Norton, 1995; Novignon *et al.*, 2012; Klein & Nicholls, 1999). These studies measured vulnerability to extreme climatic events in Ghana using national aggregates without household level data. Only a few studies have focused on the household level for example (Etwire *et al.*, 2013).

This study fills the gap in the literature by employing household data for analysis. The results from this study will contribute to better targeting of future developmental projects in the Brong-Ahafo Region of Ghana.

The results from that studies show that smallholder farming households are more vulnerable to climate and variability are useful. However, the level of vulnerability of the households needs to be well understood. From the foregoing, the following research questions will be addressed:

1. What is the level of vulnerability to climate change of smallholder maize farming households in the Brong-Ahafo Region?
2. What are the determinants of vulnerability level of climate change of smallholder maize farming households in the Region?
3. What are the constraints to climate change adaptation strategies of smallholder maize farming households in the Region?

1.3 Research Objectives

The main objective of this study is to analyze smallholder maize farming households' vulnerability to climate change in the Wenchi and Techiman Municipalities in the Brong-Ahafo Region of Ghana.

Specific Objectives

1. To assess the vulnerability level of smallholder maize farming households to climate change.
2. To estimate the determinants of vulnerability level of smallholder maize farming households to climate change.
3. To identify and rank the constraints to climate change adaptation strategies of the smallholder maize farming households in the study area.

1.4 Relevance of the Study

This study would provide insights into the household vulnerability to climate change, determinants of household vulnerability to climate change, constraints households face in adopting a strategy to mitigate climate impacts and also to suggest policy options to enhance smallholder farming households' adaptation to climate change. To reduce vulnerability. It would also explore the level of awareness of smallholder farming households about the existence of climate change.

Results from the study would provide extension agents with the information necessary to create awareness of the existence of climate change in the study area. The identified constraints would also provide information to policy makers to put in place the necessary facilities and measures to help reduce the negative impacts of extreme weather conditions associated with climate change.

The research will inform policy makers in policy making on agriculture and economic development by focusing on identifying flexible options rather than specific solutions to uncertain climate.

1.5 Organization of the Study

The study is presented in five chapters. Extensive review of the existing body of literature on climate change and variability, barrier to climate change and variability, adaptation strategies, determinants of climate change vulnerability and smallholder maize farming household levels of vulnerability to climate change, a review of the methods of analysis used by the study including others are presented in Chapter two.

Chapter three discusses the methodology of the study. It also discusses the conceptual underpinning to the empirical models used in the study, and is followed by a description of the empirical framework that is used under each of the outlined objectives of the study. The chapter also describes the method and sources of the data employed in the study.

The results and discussions of the study are presented in Chapter four, and Chapter five provides the summary, conclusions and policy recommendations. The Chapter also discusses direction for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of various literature relevant to the study. This includes definitions of the main terms and concepts; the causes, consequences, evidence and vulnerability to climate change and variability; adaptation strategies employed by smallholder farming households to mitigate climate change; climate related initiatives implemented in Ghana; barrier to adaptation strategies as well as a review of the methods of analysis employed in the study.

2.2 Definition of Terms and Concepts

This section defines key concepts such as climate change, climate variability, and vulnerability to climate change used in the literature.

2.2.1 Climate Change

Climate has generally been defined as the mean weather conditions which is found in a place over a long period of time, usually 30 years (IPCC, 2007). The scientific community has not been able to agree on an acceptable definitions of the climate change.

Numerous institutions at different points in time have emphasize on different aspects of change in their effort to define climate change. However, some common themes exist among the definitions offered by these institutions. According to the IPCC, climate change is "the significant deviation in either the average state of the climate or in its variability, which exist for a number of years normally decades or more" (IPCC,2001) .

Food and Agricultural Organization, (FAO, 2006) also defines climate change "as any change in climate over time regardless of the cause of the change". In the usage, human causes as well as the speed of change is emphasized. The phenomenon is defined as the continuing changes in the global climatic system. This results primarily from human caused global warming as a consequence of the increase and on-going emission of greenhouse gases and the loss of vegetation cover and other carbon sinks. It refers to gradual changes in climate standards.

According to Lambrou and Nelson (2010), climate change is the long term change in the state of the climate, which is intensified by changes in the averages and or changes in the variability, or changes in the occurrences or intensities of extreme events. This definition excluded the causes of climate change but rather emphasize on the signs. The definition provided by Lambrou and Nelson corroborates the IPCC and the United Nations Environment Programme (UNEP) definitions which also emphasize on the long-term nature of the change and its identification by mean level and variability.

According to ISDR/UNEP (2009), climate change may surface from natural events (internal processes or external forces) or through the activities of humans which changes the composition of the atmosphere or land use.

United Nation Framework Convention on climate Change, UNFCCC (2001) also defines climate change as a change in climate which occurs as a result of indirect or direct human activities that modifies the composition of the universal atmosphere and which is in addition to natural climate variability observed over comparable time periods. The definition provided by UNFCCC is somehow incomplete since it captures only those changes which occur as a result of indirect or direct human activities.

2.2.2 Climate Variability

According to the third assessment report of the IPCC (2001), climate variability refers to "deviations in the average state, occurrence of extremes, and standard deviations of the climate on all temporal and spatial scales beyond that of individual weather events". Climate variability may result through natural internal processes which is either within the climate system (internal variability), or deviations in natural or artificial external forces (external variability) (IPCC (2001).

The definition of IPCC does not clearly differentiate between climate change and variability. The existing definition of climate change is a change in the prevailing weather conditions that have been observed in a locality over a long period of time (30years or more), regardless of the cause of the change, whether natural variability or artificial cause. The definition does not explicitly state whether the observed changes have been permanent or temporary.

2.2.3 Vulnerability to Climate Change

Most studies have measured vulnerability in the context of natural hazards (Kelly & Adger, 2000; Downing *et al.*, 2001; Turner,2009; Parmesan & Yohe, 2003). The term vulnerability is used in many diverse ways by various intellectual communities such as poverty and food security analysis as well as natural hazards research and each of them conceptualizes it differently (Bryan *et al.*, 2009).

Several authors and existing literature (FAO, 2006; IPCC, 2007; Smith *et al.,* 2009; FAO, 2009; UNEP, 2009) have provided similar definitions of vulnerability to climate change and variability. These researchers define vulnerability as the extent at which geophysical, biological and society system prone, or at risk to, and unable to deal with the negative effect of climate change and variability.

The IPCC (2001) defines vulnerability to climate change as the degree to which a system is liable, or incapable to survive under negative effects of climate change and variability. FAO (2006) has suggested that vulnerability to climate change differs across space and time due to the numerous contributory factors. Authors (example, IPCC, 2007; Williams *et al*., 2008; FAO, 2009; UNEP, 2009) also reported that the vulnerability level of a system to climate change and variability is dependent on the character, degree, and the rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

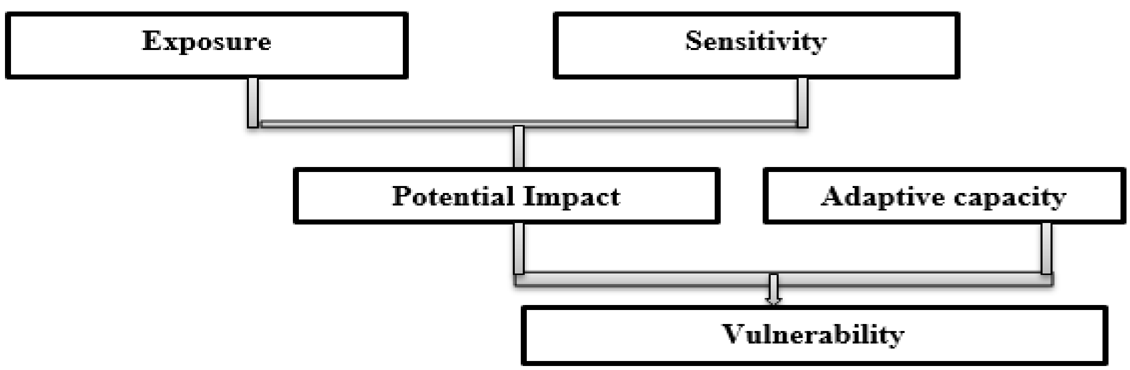

Figure 2.1: Climate Change Vulnerability and its Components
Source: Adapted from Schroter and the ATEAM consortium (2004)

Figure 2.1 shows the components of climate change vulnerability, which comprises exposure, sensitivity and adaptive capacity.

Exposure to climate change is a function of geography (IPCC, 2007). Climate change exposure is believed to be location specific. For example, communities in semi-arid areas may be most exposed to drought whereas coastal communities will have a higher exposure to sea level rise and cyclones.

Sensitivity is the extent to which a body is either adversely or beneficially, directly or indirectly affected by climate change and variability (IPCC, 2007). For example, a tropical ecosystem will be less sensitive to a decrease in rainfall than a fragile, arid or semi-arid one, due to successive influence on water flows. Also, mining community is less sensitive to changing rainfall pattern than one dependent on rain-fed agriculture for livelihood (IPCC, 2007).

Adaptive capacity is how a system is able to lessen temperate levels, the possible effects of climate change and variability by either taking advantage of prevailing opportunities or undertaking measures to deal with its consequences (IPCC, 2007; FAO, 2009).

Adaptive capacity is dynamic and is dependent on economic and natural resources, social networks, entitlements, institutions, and governance, human resources, and technology" (Barnett & Adger, 2007). Adaptation is the process by which entities such as smallholder farming households, etc. alleviate the adverse impacts of climate on their livelihoods. It also involves modifications in lifestyle and economic structure in order to reduce the vulnerability of a system to climate change and variability (Smith *et al.*, 2000). International efforts at finding solutions to climate change have recognized the role of adaptation as a policy option (Ford & Smith, 2004; Pielke, 2007).

Adaptation is one of the essential ways in decreasing the long term influences of climate change and variability (FAO, 2006). Numerous authors have lengthened this definition by adding-up adjustment in response to expected changes or stresses in the climate in order to minimize the vulnerability of natural or human systems (e.g. Tubiello *et al.*, 2007; IPCC, 2007; UNEP, 2009).

Adaptation to climate change occurs in different forms. These include anticipatory and reactive; private and public; autonomous or spontaneous and planned adaptations (UNEP, 2009). Anticipatory adaptation which is also referred to as proactive adaptation is the type where the system changes before the adverse impacts of climate change and variability are detected (IISD, 2003; IPCC, 2007).

Reactive adaptation occurs after the change is made just at the beginning of the climatic impacts (IISD, 2003). Autonomous or spontaneous adaptation varies from the other planned adaptations because it is not a mindful response to climatic stimuli but activated by ecological changes in welfare of natural and human systems (IISD, 2003).

On the other hand planned adaptation is the thoughtful policy decision, based on the awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state (IPCC, 2007).

Distinguishing between climate change and climate variability is difficult at the household level due to the dynamic nature of adaptation responses (Below *et al.*, 2012). Adaptation is employed in this study to refer to how smallholder maize farming households are either revising their practices or putting in place mechanisms to deal with or withstand the negative effect and impacts of climate change.

2.3 Evidence of Climate Change and Variability in Ghana

Ghana is a tropical country so is vulnerable to climate change and variability (Etwire, 2013). About 35% of the total landmass of Ghana is estimated to be desert and the desertification is currently estimated to be proceeding at a rate of 20,000 hectares yearly (EPA, 2009).

World Bank (2010) conducted an analysis the rainfall pattern in Ghana within and between years and reported that annual rainfall in Ghana is highly variable. The analysis showed based on historical data that rainfall was mostly high in the 1960s, but significantly reduced in the latter part of the 1970s and early 1980. A trend analysis showed a decreasing trend between 1960 and 2006 with an average decrease of 2.3 millimeters per annum.

According to Kankam-Yeboah *et al.*(2011), the climate in Ghana has changed significantly with a 1ºC increase in temperature over 30-year period based on historical data.

In the Brong-Ahafo Region of Ghana, for example, high temperature were previously recorded in March (peak of the dry season) but recently it is been recorded in January. It is now not easy to forecast the onset of the rainy season. In the past, the rainy season began in April and ended in late September or early October. However, in recent times, the rainy season starts in June or July with heavy rainfall in September or October.

It is highly anticipated that climate change will have significant impacts of climate change and variability on Ghana. There is high expectation that temperatures and rainfall will fluctuate, and the trend in temperature over the period 2010-2050 indicates warming in all regions in the country. The three northern regions in the country Northern, Upper East and Upper West are projected to experience the highest increases in temperature, while the lowest will be experienced in the Brong-Ahafo region.

Under one of the climate scenarios (Ghana Dry) for example, temperatures in the three northern regions are projected to rise by 2.1-2.4ºC by 2050. Comparatively, the projected rise in the Volta, Western, Central, Ashanti and Eastern Regions is 1.7 – 2.0ºC, and that for Brong-Ahafo region will be 1.3-1.6ºC (World Bank, 2010).

2.4 Consequences of Climate Change and Variability

Kankam-Yeboah *et al*. (2011) found that Ghana is experiencing climate change and variability already and has caused previously permanent rivers to dry up during the dry season (harmattan). More intensive rainfall events for example are the rainfall and flood events that occurred on the 23rd April 2008, 24th June 2009 and 3rd June 2015 in some parts of Accra that destroyed property and life (Etwire *et al.*, 2013). Evidence of the impacts of climate change and variability in Ghana includes the recurrent drought events that result in low levels of water in the Akosombo dam (example, the drought that resulted in hydroelectric power rationing in 2006, 2012, and still persisting).

The negative effect of climate change and variability and its vulnerability has been found to differ between genders. It affects food insecure people in different ways depending on socio-demographic factors such as age, health, and education (FAO, 2011).

According to Dunlap & McCright (2010) females compared to males are more able to express understanding to climate change and variability notwithstanding that females underrate their knowledge.

Lambrou & Piana (2006) revealed that women are mostly vulnerable to climatic stresses than men, because men usually use sophisticated means of farming such as irrigation schemes and mechanization. Women are mostly involved in less labor-intensive and subsistence agriculture.

According to the World Bank (2010), gender inequality deepens vulnerability to climate change and women are often the victims of gender based inequality in rights, household responsibilities, resources and voice. According to ISDR/UNEP (2009), women are often more vulnerable than their male counterparts in post-disaster situations. This is due to their care-giving roles which exacerbates during and after a disaster. It is also argued that females' access to resources for recovery is mostly limited.

According to Etwire (2013), women especially those in the Brong-Ahafo Region of Ghana are often constrained in terms of access and control of economic resources such as land thereby making them more vulnerable to climatic stresses.

According to Lambrou & Nelson (2010), gender of an individual influences his/her preferences with regard to longer term coping strategies. For example, while males tend to be more interested in migrating in search for wage labour, especially, in the Brong-Ahafo Region of Ghana, females tend to prefer local wage labour as a coping strategy for climate change and variability.

2.5 Climate Related Initiatives Implemented in Ghana

Several initiatives have been implemented on climate change and variability in Ghana. Table 2.1 summarizes some climate related initiatives implemented together with the beneficiaries and implementation organizations and the duration of the projects (Van Tilburg *et al.*, 2011; Etwire *et. al*. 2013).

The Netherland Climate Assistance Program started in 2003, and was intended to support farmers to adapt to climate change. The main focus of this program was to assess the linkages between poverty and climate change and the consequences of climate change on the livelihood systems of poor communities.

One of the major studies on climate change and variability adaptation in Ghana is the economics of adaptation by Van *et al*. (2011). The study focused on filling the gap in knowledge by analyzing the predicted impacts and estimating the costs of adaptation.

Community based rural development projects are an example of the many developmental projects focusing on rural development and income generation with the objectives enhancing adaptation to climate change and variability. The natural resources and environmental governance program seek to address governance issues concerning natural resources and the environment. Both Government and Non-Governmental Organization (NGOs) implemented these initiatives with donor support (Van *et al.* 2011). Table 2.1 presents a survey of the many climate-related strategies that have been done using data from Ghana.

Table 2.1: Climate Related Initiatives Implemented in Ghana

Name of initiatives	Recipient/Implementer	Start date	End date
GLOWA Volta Project	University of Bonn	01-May-00	31-May-09
Water resources management principles	Water resources commission	01-Jan-01	31-Dec-07
Climate change enabling activity (additional financing for capacity building in priority areas)	EPA	15-Feb-01	15-Feb-02
Netherlands Climate Assistant Programme (NCAP) Ghana Phase Two	ETC International	01-Jan-04	31-Dec-07
Ghana community-based rural development	MLGRD-Ministry of Local government and rural development	29-Jul-04	30-Jun-11
The Economics of Adaptation to Climate change	World bank	11-Dec-07	31-Mar-10
Non-Legal Binding Instruments on all types of forest in Ghana (UNFF/NLBI)	Forestry commission	01-Dec-08	30-Nov-10
Sustainable development of research capacity in West Africa based on the GLOWA Volta Project	Unknown	01-Jun-09	30-Nov-10
CC DARE- Climate Change and Development Adapting by Reducing Vulnerability	UNDP	01-Aug-09	30-Nov-10
Ghana natural resource and Environment governance-DPO	Government of Ghana (GoG)	03-Jun-10	30-Jun-11
Wildlife Sustainable financing study	Forestry commission		31-Dec-09

Source: Van *et al.* (2011)

2.6 Theory of Adoption

Several theories have been proposed to explain the adoption process to any innovation. Major theories include the extension theory, bounded rationality, theory of reasoned action, consumer behavior theory, and diffusion theory (Botha & Atkins, 2005).

Extension theory is based on the assumption that the rate at which an innovation is adopted is dependent on how it is communicated to the target individuals. The information about the innovation can be transmitted to the individuals through social networks or extension service (Röling & Wagemakers,1998). This implies that the adoption of an innovation will increase if it is efficiently conveyed to the target group.

The bounded rationality or the intended rational behavior theory also assumes that individuals make partly rational decisions about innovation when they are not wellinformed about it. In such situations the individual makes decision that are believed to be good and represents a reasonable or acceptable outcome.

The theory of reasoned action is based on the assumption that when an innovation is introduced to people they form attitudes with regard to it. This is done when they deliberate thoroughly on any information that they have about the subject being considered. This implies that people's behavior is interconnected with their attitudes towards a subject under study. The target group will be willing to adopt an innovation if and only if majority of them exhibit positive attitude towards it (Parminter & Wilson, 2003).

The consumer behavior theory also assumes that the needs of individuals form the basis for comparing the advantages and the disadvantages of an innovation to the pre-existing practice (Berezovskaya, 2004). The theory asserts that individuals only adopt a technology or an innovation which is useful to them.

Adoption process demands a series of stages in decision-making by individuals. It is been asserted that for an innovation to be adopted, awareness should be created first. After the individual has become aware of the technology he/she will either reject it immediately or continue to adopt when interest is gained in it. The technology may be rejected after the initial interest or the individual may proceed to the next stage by comparing the technology with existing ones. If the individual observes the outcome to be favourable, the technology will not be rejected, but it will be tested on a small scale. The individual will finally adopt the technology if it passes the test. According to Wong *et al.* (1995), although, the individual may adopt the technology in the initial stage, it may be discontinued as time go by.

According to Kopainsky & Derwisch (2009), diffusion process to an innovation can be classified into four stages. First, preliminary knowledge; this is where people who are very eager to adopt an innovation, learn and become conversant with it. Those people then are persuaded about the advantage of that innovation.

Second, the individual learns of the innovation. This is the stage where the individual forms a perception about the innovation. Third, the implementation stage; this is the stage where the individual adopts the innovation after critical assessment. Fourth, the confirmation stage; this is the stage where the individual evaluates the performance of the innovation. Rogers (1998) has also argued that the diffusion process is not a one-stage, all-inclusive theory but it involves several theoretical viewpoints.

According to Botha and Atkins (2005), the stages involved in the adoption process varies from place to place. The authors concluded that social and cultural context, climate, geography, economic condition and policy are the factors that may influence the adoption process.

2.7 Determinant of Smallholder Farming Households Vulnerability to Climate Change

According to Allen Consulting Group (2005), climate vulnerability refers to a system's potential for suffering damage or ill effects as a result of climate change.

The factors influencing smallholder maize farming households' vulnerability to climate change can be categorized as household factors, institutional factors and environmental factors. The household factors include sex of household head, age of household head, formal education of household head, total farm size, physical asset of the household, and farming experience of the household head, household size, hired labour, family labour, the number of economically active female members of household and annual household income. Institutional factors include membership in a social group and access to formal credit. Environmental factors include temperature and rainfall perception.

2.8 Constraints to Climate Change Adaptation Strategies

Several authors have given different explanations regarding barriers to climate change adaptation strategies. Barriers are defined as factors, conditions or obstacles that lessens the effectiveness of climate change adaptation strategies (Moser and Ekstrom, 2010 ;Huang et al., 2011).

These authors have tried to differentiate barriers from limits. In the fourth assessment report of the IPCC, limits were defined as conditions or factors that render adaptation strategies ineffective as a response to climate change. Adaptation strategies and the constraints associated with each has been identified by several authors' as shown in the Table 2.2.

Table 2.2: Constraints to Climate Change and Variability Strategies

Adaptation Strategies	Literature	Constraints
Planting trees, planting improved varieties of crops, diversification of livelihood activities, changing the timing of planting.	(Bryan *et al.* 2009); Huang *et al.*(2011); (Maldonado, Shearer, Bronen, Peterson, & Lazrus, 2014); (Gero, Kuruppu, & Mukheibir, 2012); (Antwi-Agyei, Fraser, Dougill, Stringer, & Simelton, 2012);	Financial
Planting early maturing varieties, using irrigation, development of early warning systems	(Jones & Boyd, 2011);(Miller *et al*. 2010); (Measham *et al.* 2011); (Adger *et al.* 2009)	Lack information on climate change characteristics
Temporary migration, changing the timing of planting.	(Adger, Huq, Brown, Conway, & Hulme, 2003), (Jones & Boyd, 2011)	Social-cultural
Planting of improved varieties of crops, Development of early warning systems, using irrigation systems.	(Jantarasami, Lawler, & Thomas, 2010); (Biesbroek *et al.*, 2010),(Bierbaum *et al.*, 2013); (Eriksen, 2009); Measham *et al.*, (2011); (Ford *et al*., 2011)	Institutional and political
Planting drought-tolerant crops, diversification of livelihoods and crops diversification.	This is related mostly to lack of resources to mitigate the adverse impacts of climate change and variability	Lack of infrastructural development including ready markets.
Developing drought-tolerant variety of crops	Most studies relate technological constraints to development of early warning systems (Boyd *et al.* 2013) as well as technical expertise in climate research see (Washington *et al.* 2006)	Technological

Source: Modified from Antwi-Agyei et al. (2013)

2.8.1 Financial Barriers

Studies (example, Peterson *et al.*, 2013; Antwi-Agyei *et al.*, 2012; Bryan *et al.*, 2009) noted that financial constraint is one of the key barriers to the climate change adaptation by smallholder farming households in Sub-Saharan Africa. This assertion was also supported by Un-habitat (2010) which reported that budget deficit has a positive effect on climate and variability in many economies in the Sub-Saharan Africa.

Bryan *et al.* (2009) suggested that financial constraint which results due to the lack of credit facility is one of the noticeable barriers to appropriate climate adaptation strategies by smallholder farming households. The assertion was supported by Peterson *et al.* (2013) who found that each adaptation strategy requires some direct or indirect cost. For example, the use of improved varieties of crops such as improved maize, is reported as one of the common adaptation strategies for smallholder farming households in the Brong-Ahafo Region of Ghana.

Poor farming households are believed to have limited amount of capital assets that may be needed to adopt a climate change strategy to reduce the adverse effects on their livelihoods (Dasgupta & Baschieri, 2010).

2.8.2 Social-Cultural Constraints

According Antwi-Agyei *et al.* (2013), the way a group of people live and their belief systems can be a barrier to climate change adaptation strategy.

Some studies (example, Jones & Boyd, 2011; Smith *et al*., 2011; Adger *et al*., 2012) have also suggested that deep value systems, beliefs, cultural practices, and the perception of group of people greatly affect their attitudes toward climate change and adaptation strategies.

Adger *et al.* (2013) stated that culture is one of the principal factors influencing the decision to adopt. It also helps in identifying risks and implementation of appropriate climate change adaptation strategies. Adger *et al.*, (2013) again reported that people who live in the same locality with dissimilar cultural backgrounds may respond differently to risks such as the negative impacts of climate change.

Moser and Ekstrom (2010) reached a similar conclusions as Adger *et al.* and concluded that people's response to risk might be greatly influenced by their pre-existing belief systems, values, and norms.

2.8.3 Lack of Information on Climate Change Characteristics

Availability and access to information on climate change is important planning and implementation of climate change strategy as well as adoption by smallholder farming households.

According to the IPCC (2007), smallholder farming households who are majority in the agricultural sector in Sub-Saharan Africa depend on climate for all their activities. However, there are few climate projections due to lack of appropriate climate data. This assertion was also supported by Adger *et al.* (2009) which revealed that information and awareness on climate change characteristics could potentially serve as a barrier to successful implementation of adaptation strategy.

According Ziervogel *et al*. (2010), data on climate change features are periodic so even when it is forecasted it may not be beneficial in the long-term planning of agricultural activities. Patt & Gwata (2002) also added to the assertion made by Ziervogel *et al* that usefulness of periodic projections on climate may be limited by issues relating to credibility, measurement, intellectual capacity, legality as well as procedural and institutional .

Antwi-Agyei *et al*. (2013) also argued that lack of adequate state of the art equipment at the meteorological agencies across the regions of Sub-Saharan Africa inhibits the well-timed prediction and forecast of the rainfall and temperature pattern. This makes it extremely difficult for smallholder farming households to make cognizant decisions on their activities which are climate dependent.

This challenge makes the smallholder farming households in most villages in Ghana to resort to the use of local agro-ecological knowledge. They also forecast the weather based on their past farm experiences, which fails most often (Antwi-Agyei *et al.*, 2013).

2.8.4 Institutional Constraint

Lamb & Davis (2003) define institution as a social bonding agent which interconnects stakeholders from access to capital of various kinds to the means of exercising power. This defines the gateways on which they pass on to positive or negative climate change adaptations.

Agrawal & Perrin (2009) reported that institutions play a significant role in a society. It helps the local communities to withstand the adverse impacts of climate variability and change. It also provides the mechanisms that help to shape the social and individual interactions within the society.

According to Biesbroek *et al*. (2013), institutions that are established by the Government play a key role in assisting the elimination of inhibitors to the adoption of climate change strategy. They also concluded that the climate change adaptation policies in many Sub-Saharan Africa countries tend to be made by few people in authority rather than the smallholder households who are affected. In most cases, these policies are compelled by the central government that has often been constrained to adaptive strategies at the regional and local levels.

According to Antwi-Agyei *et al.* (2013), in many farming communities in Sub-Saharan Africa, the supposed duties of the extension officers are to link between the research institutions and farming households. This facilitates the smooth flow of scientific method from the researchers to the farming households and the problems from the households to the researchers for the required solutions. However, in most countries the extension officers, farmer ratio is very large. This makes it extremely hard for the officers to respond to the needs of all farming households.

There has been the assertion that the lack of climate change adaptation information, including weak institutional capacity combined with the intra-annual rainfall fluctuations and rise in mean temperatures will render many households in Sub-Saharan Africa countries more food insecure.

Antwi-Agyei *et al.* (2013) suggested that institutional constraint in one way or the other has some relationship with political constraint in terms of climate change and variability. This was also supported by Ford *et al.* (2011) who reported that the lack of political will at the local levels is a major barrier to climate adaptation.

2.8.5 Technological Constraint

According to Kithiia (2011), technology is considered as one of the principal hindrances to climate change adaptation. This assertion was also supported by Smit & Skinner (2002) who argued that improvement in technology, example, the development of improved crop varieties, early warning systems as well as establishing irrigation techniques are very crucial to climate change adaptation. Due to that, these four factors are considered as the four main pillars of agricultural adaptation.

Farming households can only use the adaptation strategies and options that have been already developed (Kolikow *et al.*, 2012) and which can be applied in their dwelling places . According to Frich *et al.* (2002), it is necessary to highlight the fact that the choice of technology for climate change adaptation is also made within appropriate socio-economic, legal and institutional structure. However, countries in Africa tend to lack these structures.

According to the Africa climate report commissioned by the UK Government, low technical know-how in climate modelling is one of the key challenges to climate change research in Africa (Washington *et al.*, 2006). Enete & Amusa (2010) also reported that the technological constraint has been a major challenge in Africa. This is due to the fact governments in Africa do not budget for agriculture and climate change research.

2.8.6 Lack of Infrastructure Development

It has been reported that lack of ready market for produce by smallholder farming households is one of the major barrier to the successful implementation and adaptation of climate change strategies such as planting of crop that can withstand drought or crop diversification.

According to Antwi-Agyei *et al*. (2013), the lack of market for farm produce is interconnected with the lack of appropriate storage facilities in most Sub-Saharan African countries. This assertion was supported by Vermeulen *et al.* (2012) who posited that the lack of storage facilities weakens the trading power of the smallholder farming households compared with other agents within the agricultural marketing value chain. This normally happens during price negotiating on farm produce. This is because most of smallholder farming households cannot store their produce and therefore accept whatever price the other agents offers them for the fear that their produce will spoil.

In situations where farming households do not receive of good prices for their produce, it will be difficult for them to fulfill their credit obligations. This will have adverse effect on their ability to contract future credits to adopt a climate change strategy. It is believed that the lack of access to ready market has a link with the poor physical infrastructure development such as road networks in majority farming communities across Africa.

2.9 Review of Methodology

This section discusses the models that have been employed to achieve each of the objectives of this study as well as their justifications. These are, the Livelihood vulnerability index to ascertain the vulnerability status of the smallholder maize farming households. Generalized least squares model to assess the determinant of households' vulnerability to climate change. Kendall's coefficient of concordance to identify and rank the various constraints to the climate change adaptation strategies by the smallholder maize farming households.

2.9.1 Measuring Vulnerability of Smallholder Farming Households to Climate Change and Variability

According to Deressa *et al.* (2009), two main approaches are commonly employed to measure vulnerability to climate change and variability. These are, the indicator and the econometric techniques. The indicator approach involves selection of variables that a researcher considers to contribute to climate change vulnerability (Etwire *et al*. 2013). The main limitation of this technique is that there is some level of subjectivity in selecting the various variables that are believed to be accounting for vulnerability (Hahn *et al.*, 2009).

The econometric technique involves the application of economic, mathematical and statistical methods such as regression analysis. This approach has its drawbacks; these include the testing of various economic, mathematical, and statistical assumptions which pertains to hypothesis, standard error and the confidence intervals as well as establishing relationship between variables without making the necessary assumptions.

Hahn *et al*. (2009) employed the indicator technique to assess households' vulnerability levels in Mozambique to climate change and variability. The empirical results showed that Mabote was less vulnerable in terms of water, whereas Moma was less vulnerable in terms of socio-demographic profile. When the overall Livelihood index (LVI) was aggregated, Mabote District was more vulnerable (0.326) than Moma (0.316). The LVI-IPCC also indicated that Mabote District was more vulnerable (0.005) than Moma (-0.0074).

Etwire *et al*. (2013) also employed the indicator approach to assess households' vulnerability levels to climate change and variability in the Upper West, Upper East and the Northern Regions of Ghana. The study adapted the Livelihood vulnerability index developed by Hahn *et al*. (2009). The empirical results revealed that Northern Region was most vulnerable in terms of health, socio-demographic profile, and natural disasters and climate variability.

Upper West Region was most vulnerable to water and food, whereas the Upper East Region was most vulnerable in terms of livelihood strategies and social networks. The LVI-IPCC indicated that Northern Region was most vulnerable to climate change, followed by Upper East and Upper West Region with an indices of 0.004, -0.007 and -0.015 respectively.

Christiaensen and Boisvert (2000) employed the econometric technique to measure households' food vulnerability in Northern Mali. The study used panel data with a reference period of 1997-98. The empirical results revealed that female-headed households were less vulnerable to drought shocks compared to their male counterparts. They justified their results on the fact there is the existence of community solidarity which favours the female-headed households. Their result again revealed that households with good harvests were less vulnerable to food. The study concluded that greater dependence on agriculture by the households lessens this effect. Their empirical results further indicated that food vulnerability can be significantly reduced through off-farm employment generation in the area and greater access to irrigation infrastructure.

There are different indices that have been developed by different authors in measuring the vulnerability to climate change and variability. Swain (2011) developed composite index using the indexing and vulnerability profile method. This index is however limited to measuring households vulnerability to drought only. Deressa *et al.* (2009) developed an index which is an improvement on Swain's index. It was used to measure farmers' vulnerability to droughts and floods as well as other climatic characteristics such as hailstorms. They adapted the "vulnerability as expected poverty" approach.

This technique involves the estimation of the likelihood that a given climatic shock or set of shocks will cause a household's consumption to move below a given minimum level (for e.g., the consumption poverty line) or force the households' consumption level to stay below if the it is already there (Deressa *et al.*, 2009). The limitation of this approach is that when a vulnerability to climatic shock is captured as expected poverty, it more or less measures future and not current vulnerability. This technique measures the propensity of a household to be poor in the future as a result of climatic shocks.

Bryan *et al.* (2009) developed an aggregate vulnerability index which was used to measure farming households' vulnerability level to climate change and variability. This approach involves the selecting and aggregating a number of variables that serve as proxies for vulnerability. The selected variables are standardized and their averages are calculated to give an idea of the level of vulnerability. The main limitation of this index is that it combines both household level variables, for example, household income, and macroeconomic variables, for example, agricultural share of economy's gross domestic product (GDP). This connotes that the use of this index requires secondary data which is sometimes very difficult to obtain. Another setback of this index is that the aggregate nature of the macroeconomic data makes it insufficient to reflect the particular farming community.

An index was also developed by (Eriyagama *et al.*, 2010) to determine farming households' vulnerability levels to climate change and variability. This index combined both household and macro variables. Their approach only considered one climatic variable which was the frequency of occurrence to climatic stresses and 12 variables in computing the index. The climatic variable incorporated into the index computation measured the level of households' exposure to climate change and variability.

This study adapted the Livelihood Vulnerability index (LVI) which was developed by Hahn *et al.* (2009). The LVI takes into consideration other earlier methods of estimating the differential impacts of climate change. This index was developed based on the IPCC definition of vulnerability. This approach involves several variables which capture the level of smallholder maize farming households' exposure to natural disaster and climate change, their adaptation capacities and their sensitivity to climate change impacts (Hahn *et al.* 2009).

The computation of the index is simpler once rainfall and temperature data are available; it uses primary data from households. The LVI does not only capture the proneness to droughts and floods, but also takes into account the current vulnerability, which is useful for current planning (Etwire *et al*., 2013). The households were categorized into; low vulnerable, moderately vulnerable, highly vulnerable, and extremely vulnerable. Although, Chaudhuri (2003) posited that the choice of vulnerability threshold is arbitrary.

2.9.2 Generalized Least Squares Regression

Generalized Least Square estimation (GLS) developed by Aitken (1935) was employed to estimate the determinants of vulnerability to climate change. This is due to the advantages GLS have over the Ordinary Least Squares (Greene, 2003).

The GLS is an improved form of the Ordinary Least Squares (OLS). It was designed to give an optimal unbiased estimate where heterogeneous variance is present or when there is a certain degree of correlation between the observations. Although in such situations the parameter estimate of the OLS is unbiased and consistent, but it is inefficient (Burke, 2010).

In the presence of heterogeneity the OLS underestimates the parameter standard error which in turn affects the hypothesis testing results. One problem of the GLS is that the variance-covariance matrix is unknown (Greene, 2003).

It is also believed that the assumptions of GLS give way for heterogeneous variance within the residual. This can also be stretched to allow for non-zero covariance between the residual terms due to the fact that different forms of correlation, such as cross-correlation or serial correlation are allowed into the data. Nonetheless, the variance-covariance matrix is constant and cannot vary through time (Greene, 2003).

2.9.3 Identifying and Ranking Constraints

There are several approaches that one can employ to identify and rank constraints. One commonly used approach is the Kendall's coefficient of concordance, Garret ranking scoring and Friedman techniques. There are some differences in these ranking techniques. With the Garret ranking techniques all the ranks are converted to percentage positions after ranking. The percent positions are then converted into scores referring to the Garret's table.

According to Loganathan *et al.* (2011), the scores of the individual rankings for each are added and the mean score is estimated and arranged in either ascending or descending order. This technique has its limitations, for example, it involves more steps and it does not test the agreement between rankers. It does not also appear to test specific hypothesis.

The Kendall's ranking technique measures the extent of agreement among numerous quantitative or partial quantitative variables that are measuring a set of objects of interest. The total rank for each variable is computed and the variable with the least score is ranked as the most preferred. This technique has exhibited some similarities with the Friedman's ranking technique. This assertion was supported by Legendre (2005) who reported that there is a close relationship between the Friedman's ranking and Kendall's ranking techniques.

The two address hypotheses concerning the same data and they use the same chi-square statistic for testing. Although, these two approaches use the same chi-square statistic to test their respective null hypothesis, there is some disparity in their hypothesis formulations. In the Friedman's test the null hypotheses focus on the items being ranked, but the Kendall's test focuses on the rankers themselves. The study, therefore adopts the Kendall's coefficient of concordance to test the agreement or otherwise of smallholder maize farming households' ranking constraints pertaining to climate change adaptation strategies.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the conceptual framework that relates climate change and variability to the adaptation responses and vulnerability, constraints to climate change adaptation strategies by the smallholder maize farming households. The procedure for achieving each specific objective is also outlined as well as the description of the study area, sources and methods of data collection.

3.2 Conceptual Framework

The conceptual framework focuses on drawing linkages and explaining how climate change and variability affect smallholder maize farming households. Climate change and variability comes about as a result of internal and external factors to the smallholder maize farming households. This implies that the existence of the climate change and variability in the Brong-Ahafo region arise as a result of the activities undertaken by them and other inhabitants.

Vulnerability as a function of exposure, sensitivity and adaptive capacity determines the intensity of the adverse impact of climate change and variability on the smallholder maize farming households in the Brong-Ahafo region of Ghana as depicted in figure 3.1

The IPCC definition of vulnerability, which takes into account exposure, sensitivity and adaptive capacity, was employed for the estimation of the vulnerability indices of the smallholder maize farming households in the Brong-Ahafo region of Ghana. The exposure is said to be dependent on the magnitude and frequency of the climatic stresses.

Sensitivity is dependent on existing human and ecological conditions and capacity to adapt is also dependent on the economic and resources of the natural ecosystem.

According to Turner (2009), in order to curb or reduce the negative impact of climate change and increase their resistance, smallholder farming households adapted indigenous strategies. According to Antwi-Agyei *et al*. (2013), indigenous strategies adapted by the households are not enough to restrain the long-term climatic stress. This has led Governmental and non-governmental organizations within and outside Ghana to introduce new strategies to complement the indigenous strategies of the smallholder farming households.

Several Authors (e.g. Widyanti *et al.* 2010; Horrell and Krishnam 2007; Nyangena *et al.*, 2011; Adesina & Zinnah, 1993; Maddison 2006; Udry, 2010; Fafchamps, 1992; Fosu-Mensah *et al.*,2012; CIMMYT 1993; Feder *et al.*,1985, Mazvimavi *et al*.2014; Quisumbing 2007; Nhemachena and Hassan 2007;Deressa *et al.*,2009) have suggested that smallholder maize farming household's vulnerability to climate change is influenced by age of household head, gender of household head, economically active female household members, level of education of household head, household annual income, household physical asset, temperature perception, rainfall perception, access to formal credit, membership of local social group, family labour, farm size, years of experience of head and other socio-economic characteristics.

Due to the fact that constraints are location specific the study examined the following constraints to climate change adaptation strategies; lack of access to meteorological information, lack of access to credit, poor extension service, lack of education on climate change, lack of a ready market for produce and lack of climate change adaptation policy. When the smallholder farming households are able to overcome the constraints and adopt the strategies it will result in an increase in their production, and reduce their vulnerability level to the barest minimum or may not be vulnerable at all.

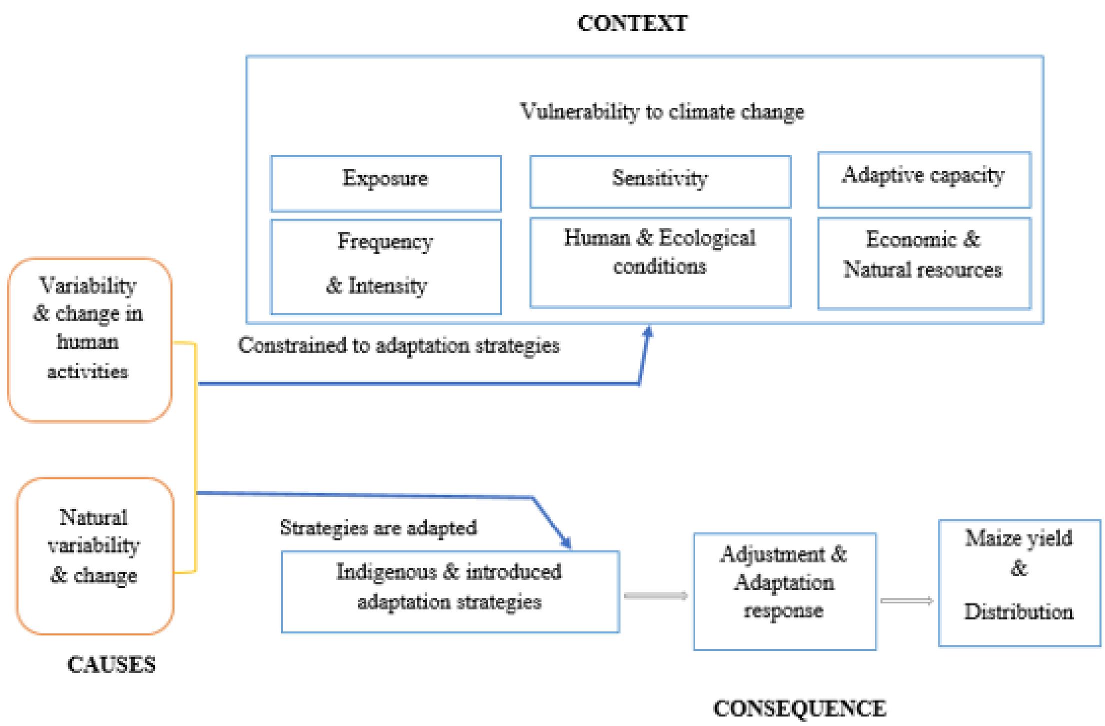

Figure 3.1: Conceptual Framework
Source: A modification of Tuner (2009) framework

3.3 Methods of Data Analysis

This section provide the tools for achieving each specific objective of the study.

3.3.1 Assessing the Vulnerability to Climate Change

Smallholder maize farming households' vulnerability to climate change and variability depends on countless factors that can either be external or internal. Vulnerability assessment defines a diverse set of approaches used to analytically integrate and study the interactions between individuals their social and physical surroundings.

According to studies (Downing *et al*., 2001; OECD, 2007), the challenging nature in quantifying the vulnerability to climate change by smallholder maize farming households' calls for composite proxy variables to be employed for analysis. Variables used to interconnect economic and biophysical qualities of systems to vulnerability outcomes through a quantitative function such as decrease in yield, land value, quality of resources or economic returns.

In aggregating variables in computing index, numerous methods has been designed. The predominant among them are the gap and weighting. The gap method involves juxtaposing the living conditions of the smallholder maize farming households before and after the occurrence of climate change and variability. The weighted approach on the hand, involves valuing each variable in order of importance to their contribution to smallholder maize farming households' vulnerability levels to climate change and variability (Hahn *et al*., 2009).

As part of this study the weighted method was employed in computing the LVI and is substantiated in the next section.

3.3.1.1 Empirical Approach for Assessing Vulnerability to Climate Change

In modelling the vulnerability to climate change by smallholder maize farming households, the balance weighted approach was employed by computing the livelihood vulnerability index as developed by Hahn *et al.* (2009) and employed by Etwire *et al.* (2013). The Livelihood Vulnerability framework is particularly relevant to understanding vulnerability to climate change because it provides a framework for analysing both the key components that make up livelihoods and the contextual factors that influence them.

The livelihood vulnerability index was derived from all the households selected for the study, taking into account the IPCC definition of vulnerability to climatic impacts developed by Hahn *et al.* (2009). It makes use of seven major components, namely socio-demographic profile, livelihood strategies, social networks, health, access to food, access to water and natural disasters and climate change.

Each component is made up of several indicators or sub-components, each of which is measured on a different scale; it is therefore necessary to standardize each as an index using either equation (3.1) or (3.2). The equation (3.1) was employed where a sub-component had a positive relationship with vulnerability whiles (3.2) was employed where a sub-component had a negative relationship with vulnerability.

$$Index_{shi} = \frac{S_h - S_{\min}}{S_{\max} - S_{\min}} \quad (3.1)$$

$$Index_{shi} = \frac{S_{\max} - S_h}{S_{\max} - S_{\min}} \quad (3.2)$$

Where S_h is the observed sub-component of indicator for household, $S_{\min}$ and $S_{\max}$ are the minimum and maximum values respectively. After each is standardized, the sub-component indicators are averaged using equation (3.2) to obtain the index of each major component:

$$M_h = \frac{\sum_{i=1}^{n} index_{shi}}{n} \tag{3.3}$$

Where M_h is one of the seven major components [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), Health (H), Food (F), Water (W), or Natural Disaster and Climate Variability (NDCV)] for household, h; $index_{shi}$ represents the sub-components, indexed by i, that make up each major component, and n is the number of sub-components in each major component. Once values for each of the seven major components for a household are calculated, they are averaged using equation (3.3) to obtain the household-level LVI:

$$LVI_h = \frac{\sum_{i=1}^{7} wM_i Mh_i}{\sum_{i=1}^{7} wMi} \tag{3.4}$$

This can also be expressed as

$$LVI_h = \frac{w_{SDP}SDP_h + w_{LS}LS_h + w_H H_h + w_{SN}SN_h + w_F F_h + w_W W_h + w_{NDC}NDC_h}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_W + w_{NDC}} \tag{3.5}$$

The weights of each major component, w_{Mi}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI. The LVI was scaled from 0 (Lowly vulnerable) to 0.6 (extremely vulnerable).

3.3.1.2 IPCC Framework for Calculating LVI

The alternative method for calculating LVI incorporated the IPCC vulnerability definition by grouping the seven major components under exposure, adaptive capacity and sensitivity (table 3.1).

Each major component comprised several sub-components or indicators, same as in LVI. Similarly, Equations (3.1)–(3.3) were used to calculate the LVI–IPCC. Instead of one weighted average as in the LVI approach, in this method three weighted averages of the major sub-components were calculated according to the three contributing factors explained in Table 1.3 using Equation (3.5):

$$CF_h = \sum_{i=1}^{n} wM_i M_{hi} \Big/ \sum_{i=1}^{n} wM_i \qquad (3.6)$$

Where CF_h, is an IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for household, h, M_{hi} are the major components for household indexed by i, w_{Mi} is the weight of each major component, and n is the number of major components in each contributing factor. Once exposure, adaptation capacity and sensitivity are calculated, the three contributing factors are combined using equation;

$$LVI - IPCC_h = (e_h - a_h) * s_h \qquad (3.7)$$

Where $LVI - IPCC_h$, is the LVI for household, h expressed using the IPCC vulnerability framework, e_h is the calculated exposure score for household h (equivalent to the natural disaster and climate variability major component). The climate variability is measured by the average standard deviation in monthly minimum and maximum temperatures and monthly rainfall over a 30-year period (Hahn *et al.*, 2009; Ashok and Sasikala, 2012; Etwire *et al*., 2013). Also, a_h is the calculated adaptation capacity score for household h (weighted average of socio-demographic, livelihood strategies, and social networks major components), and s_h is the calculated sensitivity score for household h (weighted average of the health, food, and water major components). $LVI - IPCC$ Index is scaled from -1(least vulnerable) to 1 (most vulnerable). Microsoft Office excel 2013 was employed in estimating the livelihood vulnerability index as described by Hahn *et al.* (2009).

Table 3.1 Contributing Factors to LVI Per IPCC Approach

Contributing factor	Major component
I. Exposure	Natural disasters and climate variability
II. Adaptive capacity	1. Socio-demographic profile
	2. Livelihood strategies
	3. Social networks
III. Sensitivity	1. Health
	2. Food
	3. Water

3.3.1.3 Testing for the Difference between Two Means

The Livelihood vulnerability index computed for each household was grouped under their respective Municipalities and two-sample student t-test (2-tailed) was employed to test whether there is a significant difference between the means of LVI computed for the two Municipalities. The two sample t-test was employed due to the fact that the samples are two and a within-groups design, this is a modification of the single-sample t-test.

Hypothesis Specification

Null hypothesis (H_o): There is no significant difference between the LVI means of Wenchi (μ_1) and Techiman Municipality (μ_2)

$$H_o:\ \mu_1 = \mu_2$$

Alternative hypothesis (H_A): There is a significant difference between the sample LVI means of Wenchi (u_1) and Techiman Municipalities (μ_2)

$$H_A : \mu_1 \neq \mu_2$$

Computing estimated standard Error (Standard deviation)

The standard error is estimated using equation (3.8) below.

$$\sigma_1 - \sigma_2 = \sqrt{\frac{\sigma_1{}^2}{N_1} + \frac{\sigma_2{}^2}{N_2}} \;, \qquad (3.8)$$

Which is based on the variances in each of the two samples (σ_1 and σ_2)

$\sigma_1{}^2$ denotes standard deviation of sample of Wenchi Municipality

$\sigma_2{}^2$ denotes Standard deviation of sample of Techiman Municipality

N_1 denotes Sample size of Wenchi Municipality

N_2 denotes Sample size of Techiman Municipality

The above formulae was adapted based on the theorem which assumes that samples which are independently drawn from normal populations, but that with sufficient sample size ($N1 > 50$, $N2 > 50$) the sampling distribution of the difference between means will be approximately normal, even if the original populations violates the normality assumption.

T-statistic computation

The t statistic is specified in equation (3.9) as follows:

$$t = \frac{(\mu_1 - \mu_2) - D_o}{\sqrt{\frac{\sigma_1{}^2}{N_1} + \frac{\sigma_2{}^2}{N_2}}} \qquad (3.9)$$

Decision rule: if the $tcal > tcrit$ reject the null hypothesis, otherwise do not reject the null hypothesis.

Table 3.2: Major and Sub-Component for Natural Disasters and Climate Change Variability

Major Components	Sub-components	Measurement
Water	Percent of household reporting water conflict	Percent
	Percent of household that utilize a natural water source	Percent
	Average time to water source	Minutes
	Percent of household that do not have a consistent water supply	percent
	Inverse of the average number of water stored per household	1/litres
Socio-demographic profile	Dependency ratio	Ratio
	Percent of female- headed of household	Percent
	Average age of female-headed of household	Years
	Percent of household where head of household has not attended school	Percent
	Percent of households with orphans	Percent
Livelihood strategies	Percent of households with family member working in a different community	Percent
	Percent of households dependent solely on agriculture as a source of income	Percent
	Average agricultural livelihood diversification index	1/# livelihood
Social Network	Average receive : give ratio	Ratio
	Average borrow : lend money ratio	Ratio
	Percent of households that have not gone to their local government for assistance in the past 12 months	percent
Health	Average time to health facility	Minutes
	Percent of households with family member with chronic illness	percent
	Percent of households where a family member had to miss work or school in the past 6 months due to illness	percent
	Average malaria exposure*prevention	Month*Bednet indicators
Food	Percent of households dependent solely on the family farm for food	percent
	Average number of months household struggle to find food	Number
	Average crop diversity index	1/# crops
	Percent of households that do not save crops	percent
	Percent of households that do not save seeds	percent
Natural Disaster and Climate variability	Average number of flood and drought events since 2000	Count
	Percent of households that did not receive a warning about natural disaster	percent
	Percent of households with an injury or death as a result of flood or drought since 2000	percent
	Mean standard deviation of monthly average of average maximum daily temperature since 1983	Celsius
	Mean standard deviation of monthly average of average minimum daily temperature since 1983	Celsius
	Mean standard deviation of monthly average precipitation since 1983	Millimeter

Source: Hahn *et al.* (2009)

3.3.2 Estimating the Determinants of Household Vulnerability to Climate Change

In assessing the determinants of household vulnerability to climate change, the Generalized Least Square (GLS) approach to multiple regression introduced by Aitken (1935) and used by Greene (2003) was employed for this study.

The Vulnerability index for smallholder maize farming households were computed with the Livelihood Vulnerability index designed by Hahn *et al.* (2009). The GLS model was employed instead of the OLS model by this study due its comparative advantage. According to Amemiya (1973) if the dependent variable is quantitative, then generalized least square model best fits the econometric estimation in the presence of heteroscedasticity provided all the assumptions are taken into consideration.

The generalized least squares (GLS) model is made up of $\{y_i, x_{ij}\}; i = 1......$ n $j = 1.....p$ on n statistical unit. The response values are placed in a vector $Y = (y_i, ..., y_n)'$, and they predict the design matrix placed in the design matrix $X = \|X_{ij}\|$, where X_{ij} is the value of the j^{th} predictor variable for the i^{th} unit. The model assumes that the conditional mean of Y given X is a linear function of X, whereas the conditional variance Y given X is known as Ω. This is usually written as $Y_i = X_i\beta_i + \varepsilon_i$ (3.10)

$i = 1, 2, 3.........., m$ Where $Y_i\left(n \times 1\right)$, $X_i\left(n \times k_i\right)$, $\beta_i(k_i \times 1)$ $E\left[\varepsilon / x\right] = 0$, $\text{var}\left[\varepsilon / x\right] = \Omega$. Here β is a vector of unknown regression coefficient that must be estimated from the data. If ε_{it} is the t^{th} element of ε_i, we assumed that $\left(\varepsilon_i, \varepsilon_{2t}, ...\varepsilon_{mt}\right)$ is identical, independently normally distributed with $E(\varepsilon_{it}) = 0$.

$$E(\varepsilon_{it}\varepsilon_{js}) = \begin{cases} \sigma_{ij}, if, t = s \\ 0, if, t \neq s \end{cases}$$

(Non-zero contemporaneous correlation) if we stack the m equations we have

$$\begin{pmatrix} y_1 \\ y_2 \\ . \\ . \\ y_m \end{pmatrix} = \begin{bmatrix} x_1 & 0 & . & . & . & 0 \\ 0 & x_2 & . & . & . & 0 \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ 0 & 0 & . & . & . & x_m \end{bmatrix}_{\left(nm\sum_{i=1}^{m} k_1\right)} \begin{pmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_m \end{pmatrix}_{\sum_{i=1}^{m} k_i 1} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ \varepsilon_m \end{pmatrix}_{(n,m,1)} \quad (3.11)$$

$$Y = X\beta + \varepsilon \text{, that is } E(\varepsilon) = 0 \quad (3.12)$$

$$E(\varepsilon\varepsilon)' = v = \Sigma \otimes I_n \begin{bmatrix} \sigma_{11} I_n & \sigma_{12} I_n & . & \sigma_{1m} I_n \\ \sigma_{21} I_n & \sigma_{22} I_n & . & \sigma_{2m} I_n \\ . & . & . & . \\ \sigma m1 & \sigma_{m2} I_n & . & \sigma_{mn} I_n \end{bmatrix} \quad (3.13)$$

The generalized least square estimator of β is given as,

$$\beta'_{GLS} = (X'V^{-1}X)^{-1} X^1 V^{-1} Y = \left[X'(\Sigma^{-1} \otimes I_n \right]^{-1} (\Sigma^{-1} \otimes I_n) Y \quad (3.14)$$

Matrix direct product gives $(A \otimes B)^{-1} = A^{-1} \otimes B^{-1}$ (3.15)

$$V(\hat{\beta}_{GLS}) = (X^{-1} v^{-1} X)^{-1} = \left| X'(\Sigma^{-1} \otimes In) X \right)^{-1} \quad (3.16)$$

Estimation with Generalized Least Squares

When employing the GLS model and heteroscedasticity is suspected, there are two ways to make the parameter estimate BLUE. The specification depends on whether the variance $\sigma^2{}_i$ is known or not.

Estimation under known variance, $\sigma^2{}_i$ transforming estimating equation,

$$Y_i = \beta_0 + \beta_1 . X_i + \varepsilon_i \quad (3.17)$$

$$\left(\frac{Y_i}{\sigma_i}\right)=\left(\frac{\beta_0}{\sigma_i}\right)+\beta_1\left(\frac{X_i}{\sigma_i}\right)+\left(\frac{\varepsilon_i}{\sigma_i}\right)$$

The generalized least square minimization problem is specified as;

$$\min \sum_i \varepsilon_i^2 / \sigma_i^2 \tag{3.18}$$

The variance of the error term can also be specified as;

$$v(\varepsilon_i / \sigma_i) = E\left(\varepsilon_i^2 / \sigma_i^2\right), i = 1, 2......N \tag{3.19}$$

$$=\left(\frac{1}{\sigma_i^2}\right)E(\varepsilon_i^2)=\left(\frac{\sigma_i^2}{\sigma_i^2}\right)=1 \tag{3.20}$$

The results from the transformation can be presented as; $v(\varepsilon_i / \sigma_i) = 1$ and $(\varepsilon_i / \sigma_i) \sim N(0,1)$, this implies that GLS estimate is BLUE.

The estimation of GLS when variance, $\sigma^2{}_i$ is proportional to the square of the response variable Y_i; $v(\varepsilon_i)\ \alpha\ Y_i^2 \Rightarrow v(\varepsilon_i) = E(\varepsilon^2{}_i) = k * Y_i^2$ where k is constant.

Transform the model; $\left(\frac{Y_i}{Y_i}\right)=\left(\frac{\beta_0}{Y_i}\right)+\beta_1\left(\frac{X_i}{Y_i}\right)+\left(\frac{\varepsilon_i}{Y_i}\right)$ (3.21)

Homoscedastic disturbances; $v(\varepsilon_i) = E(\varepsilon_i^2 / Y_i^2) = \left(\frac{1}{Y_i^2}\right).E\left(\varepsilon_i^2\right)$ (3.22)

Logarithmic transformation; $\ln Y_i = \alpha_1 + \alpha_1 . \ln X_i + v_i$ (3.23)

In the situation where the error variance is unknown, assumption patterning to $v(\varepsilon_i)$ is required. Error variance proportional to the square of one explanatory variable; $v(\varepsilon_i)\ \alpha\ X_i^2$ $v(\varepsilon_i) = E(\varepsilon_i^2) = k * X_i^2$ where k is constant.

Transform the model; $\left(\frac{Y_i}{X_i}\right) = \left(\frac{\beta_0}{X_i}\right) + \beta_1\left(\frac{X_i}{X_i}\right) + \left(\frac{\varepsilon_i}{X_i}\right)$ (3.24)

Then the error variance is homoscedastic;

$$v(\varepsilon_i / X_i) = E(\varepsilon_i^2 / X_i^2) = \left(\frac{1}{X_i}\right).E(\varepsilon_i^2) = \left(\frac{k.X_i^2}{X_i^2}\right) = k \text{ (Constant)} \quad (3.25)$$

Additional characteristics of the Generalized Least Squares

$E(\mu_{it}^2) = \alpha_i^2$ (Heteroscedastic)

$E(\mu_{it}\mu_{jt}) = 0\ (i \neq j)$ (Cross-sectional dependence)

$\mu_{it} = p_i\mu_i, t-1+\varepsilon_{it}$ (Auto-regression)

Where $\varepsilon_{it} \sim N(0, \alpha_{ui}^2)$, $\mu_{it} \sim N(\alpha_{ui}^2 / 1 - p_i^2)$ $E(\mu_i, t-1, \mu_{jt}) = 0$ for all

Testing for the assumption underpinning Generalized Least Square Regression

There are a lot of assumptions that underpins generalized least squares model. Due to the fact that cross-sectional data was used for this study the following assumptions were deemed testing to ascertain the validity of the estimated parameters.

Heteroscedasticity

One of the assumptions underlying the generalized least squares model is that there must be homoscedasticity which implies that the conditional variance of the error term remains constant in all independent variables, X and all time $V(\varepsilon) = E(\varepsilon_i^{\ 2}) = \sigma_\varepsilon^{\ 2} = cons\tan t$.

When this assumption is violated a problem of heteroscedasticity arise which implies that the variance of the error term, ε is different across observations.

The problem of heteroscedasticity can be detected by plotting the error against all the explanatory variables. Undertaking white test if the form of the problem is unknown and Breusch-Pagan Lagrange multiplier test can also be performed. The study employed the Breusch-Pagan Lagrange multiplier test.

$$LM = \frac{T}{2}\sum_{i=1}^{n}(\frac{s_i^{\ 2}}{s} - 1)^2 \qquad (3.26)$$

Where $s_i^{\ 2}$ the sum of group is specific squared residuals and s^2 is the GLS residuals.

H_0: Homoscedasticity~ Chi^2 with $n-1$degree of freedom, Lm-test assumes normality of residuals, not appropriate assumption not met.

The problem of heteroscedasticity can be solved by using Robust Huber-white Sandwich estimate, white heteroscedasticity constituent VC estimate.

Multicollinearity

One of the assumptions of the generalized least square model is that the independent variables in the must not highly correlate with each other. Thus the independent variables must not be near perfectly ($r = 0.7$) correlated as well as perfectly correlated ($r = 1$).

When this assumption fails, problem of multicollinearity arises which may render the parameter estimates to be less efficient.

There are several ways of detecting this problem; the variance inflation factor is specified as:

$$VIF_j = \frac{1}{1-R^2{}_j} \qquad (3.27)$$

Where R_j denotes the multiple correlation coefficient. Other methods such as correlation matrix estimation, principal component estimation can also be performed. The problem can be solved by dropping the independent variables that are perfectly or near perfectly correlated.

Endogeneity

One of the assumptions of the generalized least square model states that the explanatory variable is deterministic which implies that it must not correlate with the error term in the model. The endogeneity is specified as:

$$COV(X_i, \varepsilon_i) = E(X_i \varepsilon_i) - E(X_i) * E(\varepsilon_i) = 0 \qquad (3.28)$$

When this assumption is violated the problem of omitted variable bias, endogeneity and simultaneity emerge. The instrumental variable (IV) estimates and the Wu-Hausman test are some of the tests that can be employed to detect the presence of endogeneity in a model.

The Empirical Model is specified as:

$$LVI_i = (AGE, EDU, EXP, HSIZ, FARM, TEMP, RAIN, HAI, HLAB, FLAB, PASS, MSLG, FOC, GEN, HMEM)$$

$$Y_i = \beta_o + \beta_1(AGE) + \beta_2(EDU) + \beta_3(EXP) + \beta_4(HSIZ) + \beta_5(FARM) + \beta_6(TEMP) + \beta_7(RAIN) + \beta_8(HAI) + \beta_9(HLAB)$$
$$+\beta_{10}(FLAB) + \beta_{11}(PASS) + \beta_{12}(MLSG) + \beta_{13}(FOC) + \beta_{14}(GEN) + \beta_{15}(HMEM) + \delta_i$$

(3.29)

Where LVI_i is the vulnerability index which the dependent variable of the regression , β_o is the intercept (constant), $\beta_1.......\beta_{15}$ are the parameters to be estimated and δ_i is the disturbances term which is independent, identical normally distributed with zero (0) mean and constant variance $(\delta_i \sim N(0,\varphi^2)$. The description, measurements and a priori expectations of the variables are presented in table 3.3.

Hypothesis Testing

Z Statistic was employed to test the significance of hypothesis in relation to the different independent variables.

$$Z = \frac{\beta_i}{SE(\beta_i)} \quad (3.30)$$

The research hypotheses as follows:

Age of Household Head

H_0: The age of the household head has no significant effect on vulnerability to climate change

H_a: The age of the household head has either positive or negative significant effect on vulnerability to climate change.

Educational Level of Household Head

H_0: The educational level of the household head has no significant effect on vulnerability to climate change.

H_a: The educational level of the household head has negative significant effect on vulnerability to climate change.

Years of Farm Experience of the Household Head

H_0: The years of farm experience of the household head has no significant effect on vulnerability to climate change.

H_a: The years of farm experience of household head has a negative significant effect on vulnerability to climate change.

Household Size

H_0: The household size has no significant effect on vulnerability to climate change.

H_a: The household size has either positive or negative significant effect on vulnerability to climate change.

Farm Size

H_0: The farm size has no significant effect on vulnerability to climate change.

H_a: The farm size has a negative significant effect on vulnerability to climate change.

Temperature Perception

H_0: Temperature perception has no significant effect on vulnerability to climate change.

H_a: Temperature perception has a negative significant effect on vulnerability to climate change.

Rainfall Perception

H_0: Rainfall perception has no significant effect on vulnerability to climate change.

H_a: Rainfall perception has a negative significant effect on vulnerability to climate change.

Household Annual Income

H_0: The household annual income has no significant effect on vulnerability to climate change.

H_a: The household annual income has a negative significant effect on vulnerability to climate change.

Hired Labour

H_0: The hired labour has no significant effect on vulnerability to climate change.

H_a: The hired labour has a negative significant effect on vulnerability to climate change.

Family Labour

H_0: The family labour has no significant effect on vulnerability to climate change.

H_a: The family labour has a negative significant effect on vulnerability to climate change.

Physical Asset of Household

H_0: The physical asset of household has no significant effect on vulnerability to climate change.

H_a: The physical asset of household has a negative effect on vulnerability to climate change.

Membership of Local Social Group

H_0: The membership of local social group has no significant effect on vulnerability to climate change.

H_a: The membership of local social group has a negative significant effect on vulnerability to climate change.

Access to Formal Credit

H_0: The access to formal credit has no significant effect on vulnerability to climate change.

H_a: The access to formal credit has a negative significant effect on vulnerability to climate change.

Economically Active Female Household Member

H_0: The economically active female household member has no significant effect on vulnerability to climate.

H_a: The economically active female household member has a positive significant effect on vulnerability to climate.

Gender of Household Head

H_0: The gender of household head has no significant effect on vulnerability to climate change.

H_a: The gender of household head has a positive significant effect on vulnerability to climate change.

Decision rule: if $Zcal > Zcrit$ reject the null hypothesis, otherwise don not reject the null hypothesis.

Table 3.3: Description of Variable for the GLS Analysis

Variable	Description	Measurement	*A priori* Expectations
VI	Vulnerability	$Index(0 < LVI < 1)$	
AGE	Age of household head	Years	+/-
EDU	Formal education of household head	(1 = educated 0 = Otherwise)	-
EXP	Years of experience Household head	Years	-
HSIZ	Household size	Number	+/-
FARM	Farm-size	Hectare	-
TEMP	Temperature perception	(1 = Change ,0 = No change)	-
RAIN	Rain perception	(1 = Change, 0 = No change)	-
HAI	Household Annual income	GHS	-
HLAB	Hired Labour	(1 = Yes , 0 = No)	-
FLAB	Family Labour	Number	-
PASS	Household Physical Asset owned	GHS	-
MLSG	Membership of Local Social Group	Dummy (1 = Yes, 0 = No)	-
FOC	Access to formal Credit	Dummy (1 =Yes, 0 = No)	-
GEN	Gender of head	Dummy (female = 1 ,Male = 0)	+
HMEM	Economically active female household members (age 15-64)	Number	+

Source: Author's compilation (2015)

3.3.2.1 Justification of Explanatory Variables for the GLS Regression

Household Size

The study hypotheses a positive and negative relationship between household size and vulnerability to climate change. Widyanti *et al.* (2010) asserts that households with a high proportion of working members and less children have a low probability of being poor and vulnerable than their counterparts with less working members and more children.

Gender of the Household Head

The study hypothesized a positive relationship between female-headed households and vulnerability. Horrell and Krishnam (2007) found that female-headed household increases the probability of the household been vulnerable to climate change. Their argument was based on the fact that female headed households are usually constrained by lack of access to resources such farm inputs, credit from financial institutions and labor.

Age of Household Head

According to Nyangena *et al.*, (2011) age has a significant negative relationship with the decision to adopt a strategy. Adesina & Zinnah (1993) posits that as farmers grow older, they are less amenable to change from their old practices and so will render them vulnerable. According to Bayard *et al.* (2007) age has positive effect on the adoption of conservation measures. The study then hypotheses age of the household to be either positive or negative.

Education of Household Head

The study hypotheses a negative relationship between education of the household head and vulnerability to climate change. It is expected that a household head with some level of education have more knowledge and information about some agronomic practices and climate change strategies which can reduce the level of vulnerability, this supported by (Maddison, 2006).

Farm Experience

Farm experience by household head is expected to have a negative relationship with vulnerability to climate. According to Deressa *et al.*, (2009), it is believed that an experienced farmer who has lived in a locality for some period of time has a better knowledge about the climatic condition in the area. This makes it easy for such farmers to adapt to the changing environment compared to the others with less experience as they can give good evaluation of the environment even if they are using the indigenous knowledge method. Farm experience was measured as years of farming by the household head.

Social Groups

The study expects a negative relationship between social group and climate change vulnerability. A social group refers to people who come together and work towards a common goal. This group of people function as linkages where information is exchanged and members learn and share new innovations, discuss challenges that faces the other group members in agricultural or non-agricultural production (Udry, 2010; Fafchamps, 1992). Social groups are useful in communicating weather and climatic information.

Access to Formal Credit

According to Hassan and Nhemachena (2008) and Fosu-Mensah *et al.* (2012), household that have access to credit will not be vulnerable to climate change because it increases the opportunity for household to adapt to climate change adaptation strategies even if it comes with a cost. This study also expects a negative relationship between access to credit and vulnerability to climate change induced hazards.

Annual Household Income

The combined annual income of the household obtained from both farm and a non-farm activity is expected to have a negative relationship with vulnerability to climate change. It is believed that responses to climate change through adaptation require financial well-being Deressa *et al*, (2009). In support to this argument, CIMMYT (1993) notes that higher income households may be less risk averse and have more access to information and longer planning horizons.

Farm size

The study hypotheses a negative relationship between farm size and vulnerability to climate change. Farm size is the total landholding of a farming household. The land allocated for modern crop varieties which can withstand climatic stresses is dependent on the farm size of the household. The bigger the size of the farm, the greater the proportion of land allocated for modern crop varieties Feder *et al.* (1985), thus the bigger the farm size, the more likely the farmer is to adopt suitable strategies.

Hired Labour

The study hypotheses a negative relationship between hired labour and vulnerability to climate change. This is due to the fact that households that employ hired labour to supplement family labour in both off-farm and farm activities are able to increase their farm productivity. Hence they become less vulnerable to climate change. Than their counterpart who only depend on family labour. Mazvimavi *et al*. (2014) as well as

Adebayo and Adewumi (2008), Ajibefun and Abdulkadri (2004) assert that there is positive relationship between hired labour and productivity.

Family Labour

The study hypotheses a negative relationship family labour and vulnerability to climate change. This is due to the fact that households with more members active to be employed in their day-to-day on-farm and off-farm activities are less vulnerable than those with less active members. Quisumbing (2007) and Peterman *et al.* (2010) posit a positive relationship between family labour and higher productivity of staple crops.

Economically Active Female Household Members

The study expects a negative relationship between economically active female members of a household and vulnerability to climate change. This is due to the fact it has been already posited by Horrell and Krishnan (2007) that females are mostly constrained by resource such as inputs and credit.

Household Perception on Temperature

This study expects a negative relationship between temperature perception and climate change vulnerability. It is believed that household which perceive changes in annual mean temperature are more likely to adapt to climate change through the adoption of different practices (Nhemachena and Hassan 2007) and so render them less vulnerable.

Household Perception on Rainfall

This study expects a negative relationship between rainfall perception and climate change vulnerability. It is believed that households which perceive changes in the annual mean rainfall are more likely to adapt to climate change through the adoption of different practices (Deressa et al., 2009).

Household Physical Asset Owned

The study expects a negative relationship between physical asset that household owns and vulnerability. This is due to the fact that households with more physical asset are believed to be less vulnerable than their counterpart with less, because in times of need the former can liquidate some of the assets which can be used to adapt a strategy to mitigate adverse climate change.

3.3.3 Identifying Constraints to Climate Change Adaptation Strategies

This objective was achieved by reviewing literature to identify the constraints. The identified constraints (access to credit, ready market for produce, extension service, access to meteorological information, access to improved crop varieties, education on climate change, climate change adaptation policy) were pre-tested and presented to the respondents for ranking. The ranking was done from the most pressing to the least pressing using numeric scales 1, 2, 3…. 7. The total rank score of each constraint was calculated and the constraint with the last score was ranked as the most pressing one, whereas the constraint with the highest score ranked as least.

The Kendall's coefficient of concordance (W) was used to measure the degree of agreement among the rankings of the constraints by the respondents using their rank scores. The coefficient of concordance (W) has positive value ranging between zero (0) and one (1). It is one in the situation where the ranks assigned by each household are the same as those assigned by other households and zero when there is a maximum disagreement among the households.

Given that T represents the sum of ranks of each factor being ranked, the variance of the sum is given by;

$$\text{var}_T = \frac{\sum \text{T}^2 - (\sum T^2)/n}{n} \tag{3.31}$$

Variance, is maximum variance of T is then given by

$$\frac{m^2(n^2-1)}{12} \tag{3.32}$$

Where, m = Number of sets of ranking by the farmers and n = the number of specific constraints being ranked.

The coefficient concordance (W) is therefore given as,

$$W = \frac{\left[\sum T^2 - (\sum T^2)/n\right]/n}{m^2(n^2-1)/12} \tag{3.33}$$

Equation (3) is further simplified to the computational formula as;

$$W = \frac{12\left[\sum T^2 - (\sum T^2)/n\right]/n}{nm^2(n^2-1)} \tag{3.34}$$

The hypothesis and the significance of the rankings are further assessed using the chi-square (χ^2) test as follows:

The null (H_o) and the alternative (H_a) hypothesis are stated as follows;

H_o: There is no agreement among the rankings of the constraints by the households

H_a: There is agreement among the rankings of the constraints by the households

The coefficient of concordance (W) may be tested for significance in terms of the chi-square (χ^2) distribution: It is given as,

$$\chi^2 = \lambda(n^2 - 1)W/(k+1) \tag{3.35}$$

With $n-1$degree of freedom, the parameter k is the number of constraints presented at one time. $k = n-1$

λ = depicts the number of times that a given comparison occurs.

Decision rule: If the chi-square (χ^2) calculated from the simulation is greater than the relevant critical χ^2 from Fisher's chi-square (χ^2) statistics distribution, the null hypothesis is rejected.

3.3.4 Statistical Software Application and Presentation of Results

The statistical tools employed for analyzing the result are; STATA version (13), SPSS version (21) and Microsoft Excel version (2013). The data was presented in the form of tables, figures, frequencies and percentages.

3.3.5 Data and Data Source

The study employed both primary and secondary data. The primary data was collected from smallholder maize farming households in the Brong-Ahafo Region of Ghana. A questionnaire was designed, tested and administered at the household level. The questionnaire covered 31 key variables which were used in computing the Livelihood vulnerability index as well as other variables to achieve the other objectives.

Secondary data on temperature and rainfall were also collected from the Ghana Meteorological Agency. The reference period for most of the survey questions was between 2000 and 2015. The reference period for the meteorological data was between 1983 and 2013. This year range was chosen based on the definition of change in climate which is believed to be taking place every three decades. Information pertaining to climate change and variability in the world, Africa and Ghana was obtained from sources such as journals, text books and project reports.

3.3.6 Study Area

This section provides description of the study area chosen for the study.

Wenchi Municipality

The Wenchi Municipality is located in the western part of Brong-Ahafo Region of Ghana. It is located at the northeast of the regional capital (Sunyani). It lies between latitudes 7.300 and 8.050 North and longitudes 2.150 and 1.550 West. It covers the moist-deciduous forest and the Guinea Savanna woodland vegetation zone (GSS, 2010).

The rainfall pattern is characterized by seasonality, which is a limiting factor in agriculture and plant growth. The average annual rainfall is about 1140-1270mm with an average maximum temperature of about 30.9 ^{0}C and a minimum of 21.20C. Temperature in the Municipality is generally high, averaging about 24.5 ^{0}C. The average maximum temperature is 30.9 (^{0}C) and a minimum of 21.2 (^{0}C). The hottest months are February to April (GSS, 2010).

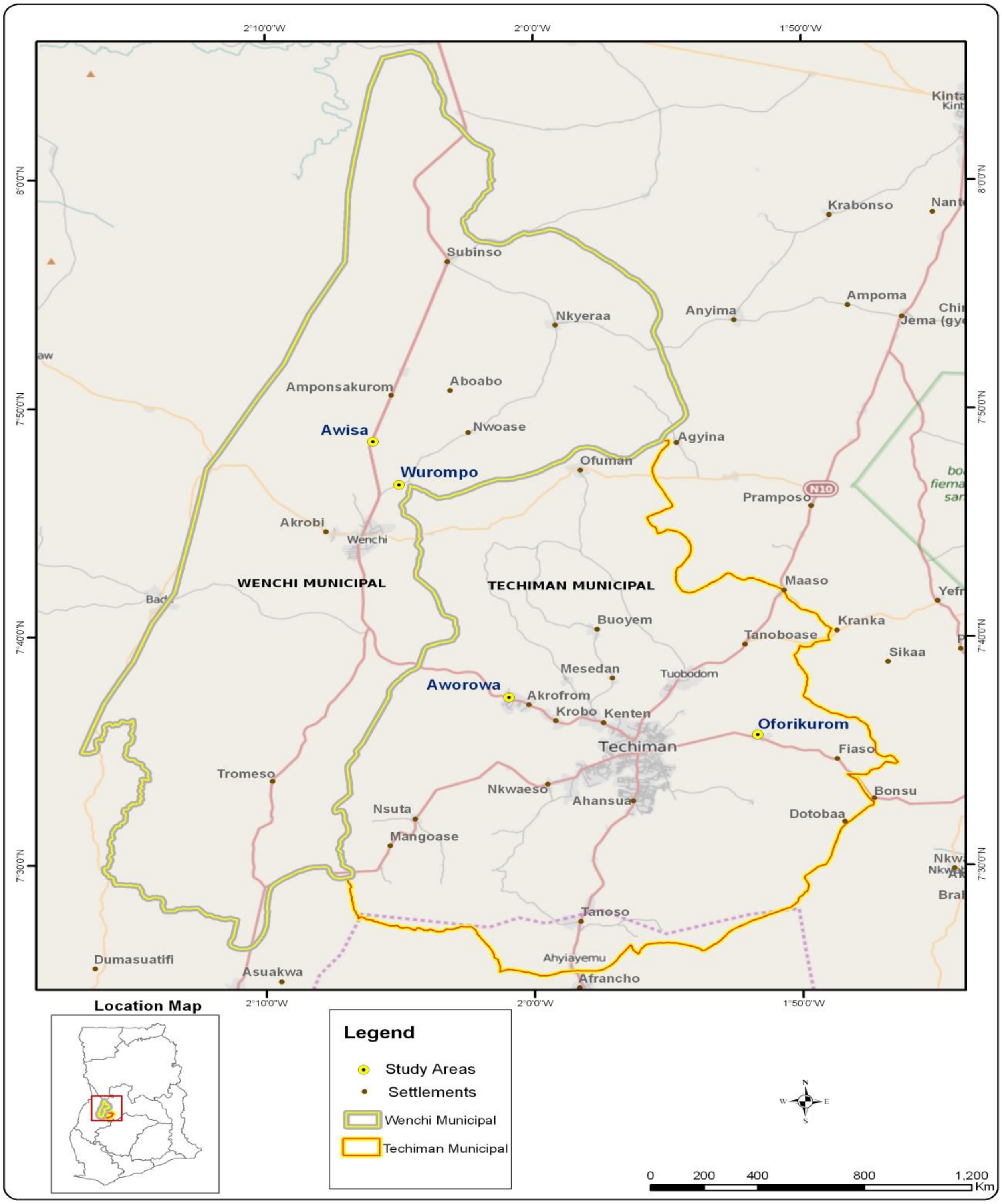

Figure 3.2: The Map of Techiman and Wenchi Municipalities and their communities chosen for the study

Source: Geography Department, University of Ghana

Techiman Municipality

Techiman Municipality lies between longitudes 10 49'East and 20 30' West and latitudes 80 00' north and 70 35' South. The Municipality shares common boundaries with Wenchi Municipality Kintampo South District to the North-East to the North and West, Offinso-North District (in the Ashanti Region) to the South and Nkoranza South District to the South-East. Total land area is 669.7 square kilometers (GSS, 2010).

Techiman Municipality experiences both semi-equatorial and tropical conventional or savanna climates, characterized by moderate to heavy rainfall annually. The Municipality records highest rainfall (over 1650mm) in the south-west and declines northwards to about 1250mm in the North West Guinea-savanna zone around Offuman area. It has an annual average temperature of $28^{0}C$ and a relative humidity of 75-80% in the rainy season and 70-72% for the rest of the year (GSS, 2010).

The Municipality has three main vegetation zones, namely, the Guinea-Savanna woodland, located in the north-west, the semi-deciduous, zone in the south and the Transitional zone, which stretches from the southeast and west up to the north of the municipality. The major land uses are crop production and animal production.

3.3.7 Sampling Procedure

A multi-stage sampling procedure was employed in this study. First, the Brong-Ahafo Region was purposively selected due to the predominance of the smallholder maize growers compared to the other Regions in the country.

Second, Simple random sampling was conducted. In this respect, ecology, population, and land size where considered to select two (2) Municipalities: Techiman and Wenchi.

Third, the simple random sampling technique was again employed to select 2 communities from each of the Municipalities. In this regard, Aworowa and Oforikurom were the two (2) communities selected from the Techiman Municipality, whereas Wurompo and Awisa were selected from the Wenchi Municipality. Fourth, Seventy five (75) smallholder maize farming households were randomly selected from each Municipality. Thus, a total of one hundred and fifty (150) maize growing households were enumerated from the two Municipalities.

Table 3.4: Distribution of Households Surveyed

Municipality	Community	Number
Techiman	Aworowa	40
	Oforikurom	35
Wenchi	Wurompo	40
	Awisa	35

Source: Author's computation from field survey (2015)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results of the study. It provides a description of the socio-economic characteristics of the sampled respondents. This is followed by the discussion of the Livelihood Vulnerability indices computed for the two Municipalities. The results of the determinants of the vulnerability levels of maize farming households to climate change are discussed. Finally, the results of the constraints that militate against the households' adaptation of climate change strategies are also discussed.

4.1 Presentation of Results

This section presents the results from the analysis done to achieve each specific objective.

4.1.1 Socio-Economic Characteristics of the Respondents

A total 150 smallholder maize farming households were interviewed for the study; 75 each from Techiman and Wenchi Municipality.

Gender

Table 4.1 indicates that about 84% of the household heads in the Wenchi Municipality were male and 16% were female. The same applies to the Techiman Municipality where 72% were male and 28% female. The pooled sample also exhibited similar result with 78% male and 22% female.

This result is consistent with the Regional analytical report out of the Population and Housing Census, which reported that in terms of gender of household head, the male population is bigger than the female by 65.30% in the Brong-Ahafo Region of Ghana

GSS (2010). The GSS (2010) again reported that 52.7% of the household involved in agriculture are males with 47.3% female this is attributed to the fact that agriculture is labour intensive and so males are the majority.

Table 4.1: Gender of the Household Head

Gender	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Male	63	84	54	72	117	78.00
Female	12	16	21	28	33	22.00

Source: Author's computation from field survey (2015)

Age

Table 4.2 indicates that 17.33% of the household heads in the Wenchi Municipality were within the age category 20-34years, 26.67% within 35-49years, 28 % were within both 50-64years and above 65 years categories. In the Techiman Municipality, 8% were within 20-34years, 24% within 35-49years and 38.67% within 50-64 whiles 29.33% were above 65 years. The pooled sample also indicates that 12.67% fell within 20-34years, 25.33% within 35-49 years and 33.33% within 50-64years whiles 28.67% were above 65 years.

The result from the PHC indicates that 29.9% of the household heads in the Brong-Ahafo Region were within the age category of 20-34 years, 34.1% were within the ranges of 35-49, 20.7% within 50-64 and 13.4% were 65 years and above (GSS, 2010).

Table 4.2: Age of Household Head

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
20-34	13	17.33	6	8.00	19	12.67
35-49	20	26.67	18	24.00	38	25.33
50-64	21	28.00	29	38.67	50	33.33
Above 65	21	28.00	22	29.33	43	28.67

Source: Author's computation from field survey (2005)

Marital status

Table 4.3 indicates that 14.67% of the household heads in the Wenchi Municipality were single, 72% were married, 8% were divorced and 5.33% were widowed. Techiman Municipality also recorded 22.67% to be single, 58.67% to be married, and 14.67% divorced whiles 4% were widowed. The pooled sample also indicates that 18.67% of the household heads were single, 65.33% were married, and 11.33% were divorced and 4.67% were widowed. This result is consistent with GSS (2010), which reported that about 45.4% of the population in the rural locality was married, 38.9% of them were single, 3.6% were divorced, and 4.2% were widowed.

Table 4.3: Marital Status of Household Head

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Single	11	14.67	17	22.67	28	18.67
Married	54	72.00	44	58.67	98	65.33
Divorced	6	8.00	11	14.67	17	11.33
Widowed	4	5.33	3	4.00	7	4.67

Source: Author's computation from field survey (2015)

Access to Formal Credit

Table 4.4 indicates that in the Wenchi Municipality only 6.67% of the households had access to formal credit and 93.33% had no access to formal credit. In the Techiman Municipality only 24% of the households had access to formal credit and 76% had no access. From the pooled sample only 15.33% of the households had access to formal credit whiles 84.67% of them had not. This implies that the majority (84.67%) of the smallholder maize farming households in the Brong-Ahafo Region had no access to credit.

Table 4.4: Access to Formal Credit

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Yes	5	6.67	18	24.00	23	15.33
No	70	93.33	57	76.00	127	84.67

Source: Author's computation from field survey (2015)

Local Social Groups

Table 4.5 indicates that in the Wenchi Municipality 34.67% of the respondents belonged to a local social group whiles 65.33% of the respondents did not belong to any local social group. In the Techiman Municipality, 30.67% of the respondents belonged to a local social group whiles 69.33% of the respondents did not belong to any local social group. The pooled sample shows that 32.67% of the respondents belonged to a social group whiles 67.33% of the respondents did not belong to a social group. This implies that the majority (67.33%) of the respondents in the Brong-Ahafo Region did not belong to any local social group.

Table 4.5: Local Social Group

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Yes	26	34.67	23	30.67	49	32.67
No	49	65.33	52	69.33	101	67.33

Source: Author's computation from field survey (2015)

Hired Labour

Table 4.6 indicates that about 78.67% of the households in the Wenchi Municipality employed hired labour to supplement their family labour whiles 21.33% did not employ hired labour. In the Techiman Municipality, 50.67% of the households employed hired labour whiles 49.33% did not. The pooled sample shows that 64.67% of the households employed hired labour for their activities whiles 35.33% did not employ hired labour.

This implies that the majority (64.67%) of the smallholder farming households in the Brong-Ahafo Region employs hired labour for their off and on-farm activities.

Table 4.6: Hired Labour

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Yes	59	78.67	38	50.67	97	64.67
No	16	21.33	37	49.33	53	35.33

Source: Author's computation from field survey (2015)

Extension Service

Table 4.7 indicates that about 49.33% of the respondents in the Wenchi Municipality had access to extension service whiles 50.67% had no access. In the Techiman Municipality only 24% of the households had access to extension service whiles 76% of the households had no access extension service. For the pooled sample, 36.67% of the respondents had extension service access whiles 63.335% had no access.

Table 4.7: Extension Service

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Yes	37	49.33	18	24.00	55	36.67
No	38	50.67	57	76.00	95	63.33

Source: Author's computation from field survey (2015)

Educational Level

Table 4.8 indicates that 61.33% of the respondents in the Wenchi Municipality had basic education, 6.67% of them had secondary education, 6.67% of them had tertiary education whiles 25.33% of the household heads had no formal education. In the Techiman municipality 44% had basic education, 1.33% of them had secondary, 5.33% of them had tertiary education whiles 49.33% of them had no formal education.

The pooled sample shows that 52.67% of the respondents had basic education, 4% of them had secondary education, 6% had tertiary education whiles 37.33% of them had no formal education. This result is consistent with the GSS (2010) which revealed that about 51.7% of the population in the region had basic education with respect to Wenchi and the pooled sample but the results for the Techiman Municipality high above the regional average.

Table 4.8: Educational Level of respondents

	Wenchi		Techiman		Pooled	
	Freq.	%	Freq.	%	Freq.	%
Basic	46	61.33	33	44.00	79	52.67
Secondary	5	6.67	1	1.33	6	4.00
Tertiary	5	6.67	4	5.33	9	6.00
None	19	25.33	37	49.33	56	37.33

Source: Author's computation from field survey (2015)

Temperature Perception

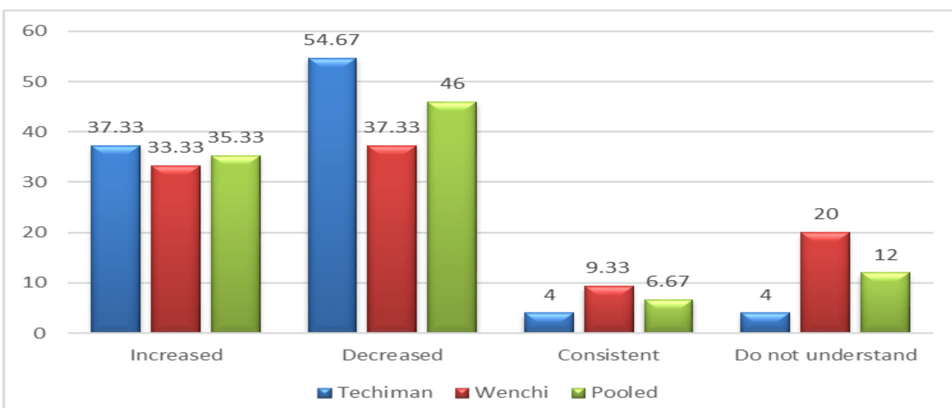

Figure 4.1: Temperature Perception
Source: Author's computation from field survey (2015)

Figure 4.1, shows that 73.33% of the respondents in the Wenchi Municipality perceived that the temperature had increased over the years, 9.33% perceived a decrease and consistency respectively whiles 8% did not understand the changes in temperature intensity.

About 69.33% of the respondents in the Techiman Municipality perceived an increase in the temperature over the years, 21.33% perceived a decrease, 6.67% perceived consistency in the temperature intensity whiles 2.67% of the respondents did not understand.

The pooled sample also indicates that 71.33% of the respondents perceived an increase in the temperature. 15.33% perceived a decrease in the temperature. And 8% perceived consistency in the temperature whiles 5.33% of the respondents did not understand.

To get information on the climate change respondents were asked whether they have observed any change in the intensity of the temperature over the past 30 years. The response of the respondents was in line with Deressa (2007) which reported that there has been an increase in temperature over the years. The result also agrees with Kankam-Yeboah *et al.* (2011) which reported that there is the existence of climate change in Ghana. The result is also in line with Fosu-Mensah *et al*. (2012) which reported that majority of its respondents perceived an increase in the temperature. One may conclude that the perceptions of the respondents pertaining to changes in temperature are in consistent with the fluctuations in the mean annual temperatures as shown in figure 4.2.

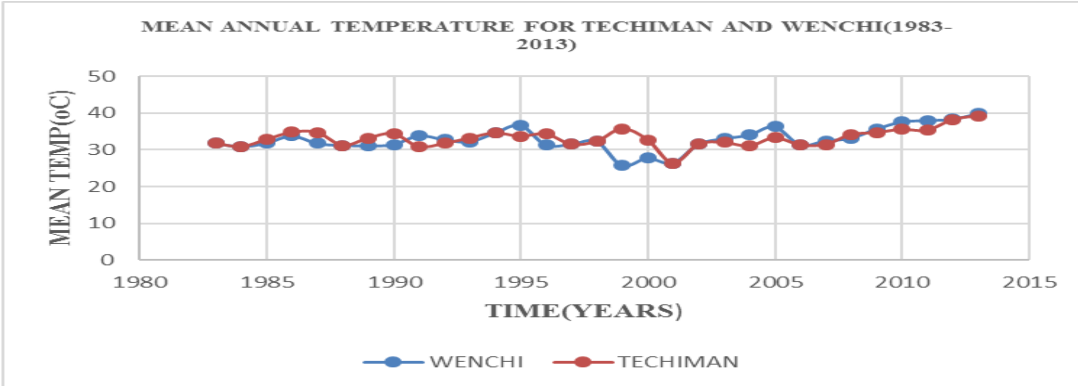

Figure 4.2: Historical mean annual temperature in Techiman and Wenchi Municipalities in Ghana

Source: Author's computation from field survey (2015)

Rainfall perception

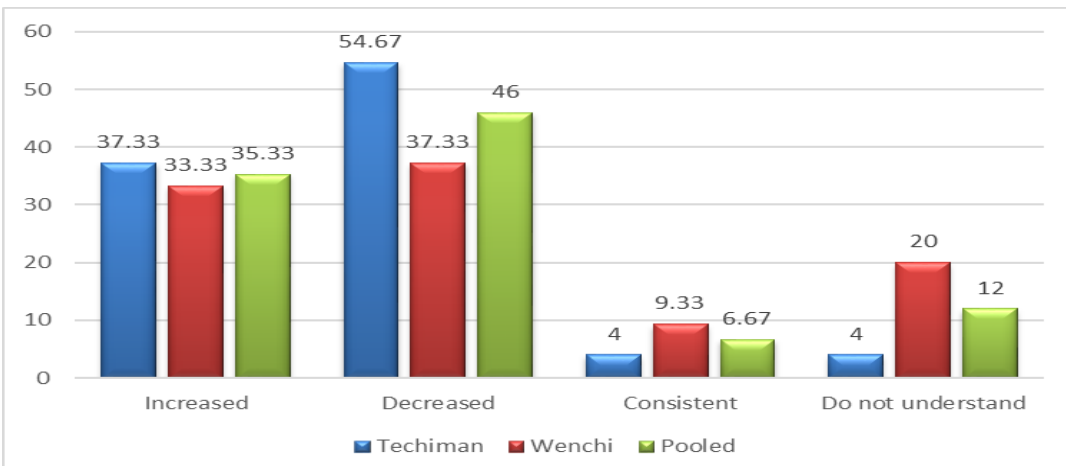

Figure 4.3: Rainfall perception

Source: Author's computation from field survey (2015)

From the figure 4.3, chart it can be inferred that 33.33% of the respondents in the Wenchi Municipality perceived an increase in the rainfall amount, 37.33% perceived a decrease in the rainfall amount, 9.33% perceived consistency whiles 20% did not understand. About 37.33% of the respondents in the Techiman Municipality perceived an increase in the amount of rainfall, 54.67% of the respondents also perceived a decrease, and 4%

perceived consistency in the rainfall amount over the past three decades whiles 4% of the respondents did not understand.

The pooled sample indicates that 35.33% of the respondents perceived an increase in the amount of rainfall, 46% of the respondents perceived a decrease, and 6.67% perceived a consistency in the amount of rainfall over the past years whiles 12% of the respondents did not understand. To get information on the climate change respondents were asked whether they have observed any changes in the amount of rainfall in the past three decades.

Responses of the respondents were consistent with Deressa (2007) who reported a decreasing trend in the amount of rainfall. The result is also consistent with Kankam-Yeboah *et al.* (2011) which reported that there is the existence of climate change in Ghana. It is also agrees with Fosu-Mensah *et al.* (2012) which reported that majority of its respondents perceived decrease in the amount of rainfall over the years. The perceptions of the respondents about the fluctuation in the rainfall pattern are consistent with the historical mean annual rainfall pattern depicted in figure 4.3.

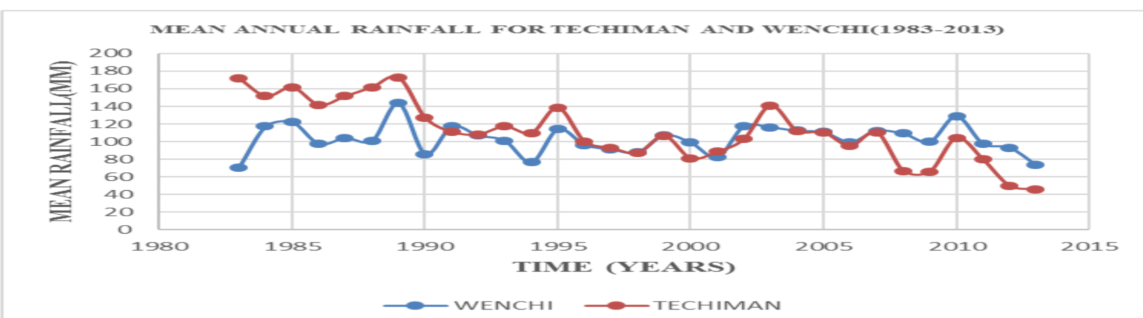

Figure 4.4: Historical mean annual rainfall in Techiman and Wenchi Municipalities in Ghana

Source: Author's computation from field survey (2015)

Table 4.9: Means of Socio-economic characteristics

Variable	Wenchi				Techiman			
	Mean	Std. Dev.	Min	Max.	Mean	Std. Dev.	Min.	Max.
Farm Experience (Years)	27.90	14.68	3	56	32.16	16.38	3	65
Household physical asset (GHS)	1088.43	20354.7	20	133460	3806.53	16310.72	30	138000
Household size (Number)	7.52	4.07	1	20	10.35	6.42	3	40
Economically active female household members (Number)	4.32	2.39	1	11	6.50	4.38	1	29
Farm size (Ha)	2.95	2.61	0.4	16	3.14	3.11	0.4	16.8
Family Labour (Number)	4.4	2.57	1	13	6.55	4.38	1	29
Household annual income (GHS)	2980	2803.82	106	11670	3898.56	12025.74	100	85500

Source: Author's calculation from Field Survey (2015)

Household size

The average household size in the Wenchi Municipality is 7 with a maximum of 20, minimum of 1 and a standard deviation of 4. The average household size of the respondents is above the Municipal average of 4.6 as well as the regional average of 4.6 (GSS, 2010). The average household size of the Techiman Municipality was 10, maximum of 3, maximum of 40 and standard deviation of 6. The average household size is above the Municipal average of 4.3 and Regional average of 4.6 (GSS, 2010). This outcome was expected due to the fact that agricultural household sizes are generally higher than general household sizes due to the labour requirements of agricultural activities.

Farm Experience of Household Head

The average years of farm experience for household heads in the Wenchi Municipality was 27.90 years, minimum age of 3 years, maximum age of 56 years with a standard deviation of 14.68. The mean years of farm experience of the household heads in the

Techiman Municipality was 32.16, minimum of 3 years, maximum of 65 years and a standard deviation of 16.38

Household Physical asset owned

The average physical asset owned by households in the Wenchi Municipality was valued at GHS 1088.43, with minimum valued at GHS 20.00, maximum valued GHS133460.00 and a standard deviation of GHS20354.70. The average physical asset owned by the households surveyed in the Techiman Municipality was also GHS 3806.53, with a maximum value of GHS 138000.00, minimum of 30 and standard deviation of GHS 16310.72.

Economically active Female household members

Table 4.9 indicates that in the Wenchi Municipality average number of economically active female members of a household was 4 with a minimum of 1, maximum of 11 and standard deviation of 2. In the Techiman Municipality, the average number of economically active female members of a household was 6, with a minimum of 1, maximum of 29 and standard deviation of 4.

Farm size

Table 4.9 depicts that the average farm size of the households in the Wenchi Municipality is 2.95ha, with minimum of 0.4ha, maximum of 16ha and a standard deviation of 2.61. The average is below the regional smallholder farm size average of 3.5ha (Chamberlin, 2008). The average farm size of households in the Techiman Municipality is 3.14ha with a minimum of 0.4ha, maximum of 16.8ha and standard deviation of 3.11ha.This average is also below the regional average.

Household Annual Income

Table 4.9 shows that the mean annual income of the households in the Wenchi Municipality is GHS 2980.00 with minimum of GHS106.00, maximum of GHS 11670.00 and standard deviation of 2803.82. The mean annual income recorded in the Wenchi Municipality is above the regional average of GHS1202.00 (GSS, 2008). The average for Techiman Municipality was GHS3898.56 which is far above the regional average of GHS1202.00 (GSS, 2010) with maximum of GHS 85500.00, minimum of 100.00 and standard deviation of 12025.74.

Family Labour

Average family labour employed by households in the Wenchi Municipality for their farming activities was 4.4, with a minimum of 1, maximum of 13 and standard deviation of 2.57. The Techiman Municipality had a mean of 6.55 with a standard deviation of 4.38, minimum of 1 and maximum of 29.

4.1.2 Assessing Vulnerability Levels of Households to Climate Change

The vulnerability level of each household was computed. It was based on 31 key variables which were grouped under seven major components, namely; water, socio-economic profile, food, social network, livelihood strategies, natural disaster and climate variability and health. The employed the Livelihood vulnerability index designed by Hahn *et al.* (2009). Through the same procedure the LVI for the two Municipalities were computed as shown in table 4.10.

4.1.2.1 Categorization of Vulnerability Levels of the Households Surveyed

The Livelihood Vulnerability Index was used to establish the vulnerability status of the studied households. The classification of the households was adapted from FANRPAN (2011).

The households were classified as; lowly vulnerable, which are households that are in a vulnerable situation, but can still cope; moderately vulnerable households are those that need urgent, but temporary assistance in case of a shock and the extremely vulnerable households are those that are almost at a point of no return. This study, however, included one category which is highly vulnerable households, which are those that need very urgent assistance.

Table 4.10 Livelihood vulnerability status of the households (Pooled Sample)

Vul. category	LVI range	Situation of households	F	%
Lowly vulnerable	0.201-0.300	Coping household-household in a vulnerable situation, but still able to cope.	53	35.3
Moderately vulnerable	0.301-0.400	Households need some temporary assistance to recover when hit hard	58	38.7
Highly vulnerable	0.401-0.500	Households need urgent assistance to recover	37	24.7
Extremely vulnerable	0.501-0.600	Emergency level household- the equivalent of an intensive care situation could be resuscitated only with the best possible expertise	2	1.3

Source: Author's computation from field survey (2015) & FANRPAN (2011)

Table 4.10 reports the results from the pooled sample of 150 respondents. About 35.3% were lowly vulnerable to climate change, 38.7% were moderately vulnerable, 24.7% of the households were highly vulnerable and only 1.3% were extremely vulnerable. This implies that the majority (38.7%) of the households in the Region were moderately vulnerable.

Table 4.11: Livelihood vulnerability status of Techiman and Wenchi Municipalities

LVI range	Category	Wenchi		Techiman	
		Freq.	**%**	**Freq.**	**%**
0.201-0.300	Lowly vulnerable	30	40	23	30.7
0.301-0.400	Moderately vulnerable	33	44	25	33.3
0.401-0.500	Highly vulnerable	11	14.7	26	34.7
0.501-0.600	Extremely vulnerable	1	1.3	1	1.3

Source: Author's computation from the field survey (2015) & FANRPAN (2011)

Table 4.11 compares the vulnerability status of the maize farming households in both Techiman and Wenchi Municipalities. About 40% of the respondents in the Wenchi Municipality were lowly vulnerable, 44% were moderately vulnerable, 14.7% were highly vulnerable whiles 1.3% were extremely vulnerable. This implies that a large proportion of the households in the Wenchi Municipality were moderately vulnerable. In the Techiman Municipality 30.7% were lowly vulnerable, 33.3% were moderately vulnerable, 34.7% were highly vulnerable whiles 1.3% were extremely vulnerable. This implies that large proportion of the households in the Techiman Municipality were highly vulnerable.

Table 4.12 presents the LVI sub-component values for each municipality as well as their minimum and maximum values. The major component and the composite LVI for each municipality are also presented. Empirically, the vulnerability indices of the major component ranged from 0.183-0.577. The indices being relative values are compared across the two Municipalities in the Brong-Ahafo region of Ghana within the study sample only.

The vulnerability index of the water component of the LVI showed that Wenchi Municipality is more vulnerable (0.295) than Techiman Municipality (0.183). Wenchi Municipality recorded a higher percentage (41.95%) of households reporting conflicts over water resources in the past than Techiman (9.770%).

Wenchi recorded a higher percentage (14.67%) of households that utilize natural water source than Techiman (1.130%). Utilization of a natural water source such as dam, lake and among others has a higher probability of leading to an increase in household's vulnerability to water borne diseases and water scarcity during the dry season (Etwire *et al.*, 2013). The average time taken to reach a water source is found to be higher in the Wenchi Municipality than Techiman.

Water is mostly collected by women and children, due to the short distance to water sources in the communities in both Municipalities it decreases the time burden of household chores and slightly affects time for care in the case of the women and school attendance in the case of the children.

Wenchi Municipality reported a higher percentage (47.62%) of households that do not have a consistent water supply and Techiman had (19.75%).

Due to the availability of pipe and bore holes in both Municipalities, the households are not affected much during the dry season when most natural water sources tend to dry up. More households in the Techiman Municipality reported storing water daily compared to those in the Wenchi Municipality.

The second major component is the socio-demographic profile which consists of five sub-components. Wenchi showed greater vulnerability (0.246) on the socio-demographic profile index than Techiman (0.228). About 37.33% of the household heads in the two Municipalities have no basic education. Formal education tends to improve the ability of smallholder maize farming households to better appreciate issues disturbing them and therefore look for possible solutions at the appropriate places (Etwire *et al.*, 2013).

Illiteracy limits smallholder maize farming households' access to information, especially from written sources, thereby increases their susceptibility to climatic stresses.

Table 4.12: Indexed sub-components, major component for natural disasters and Climate change and overall LVI for both Wenchi and Techiman Municipalities

Sub-component	Wen.	Tech.	Major component	Wen.	Tech.
Percent of household reporting water conflict	0.420	0.098	**Water**	**0.295**	**0.183**
Percent of households that utilize a natural water source	0.147	0.011			
Average time to water source	0.220	0.200			
Percent of households that do not have a consistent water supply	0.476	0.201			
Inverse of the average number of liters of water stored per household	0.210	0.405			
Dependency ratio	0.140	0.105	**Socio-demographic profile**	**0.246**	**0.228**
Percent of female-headed households	0.181	0.293			
Average age of female head of household	0.440	0.250			
Percent of households where the head has not attended school	0.289	0.230			
Percent of households with orphans	0.173	0.260			
Percent of households dependent solely on family farm for food	0.640	0.813	**Food**	**0.257**	**0.252**
Average number of months, households struggle to find food	0.149	0.125			
Average crop diversity index	0.364	0.150			
Percent of households that do not save seeds	0.040	0.040			
Percent of households that do not save crops	0.093	0.130			
Average Receive: Give ratio	0.292	0.280	**Social Networks**	**0.577**	**0.516**
Average Borrow: Lend	0.440	0.330			
Percentage of households that have not gone to their local government for assistance in the past 12 months	1.000	0.933			
Percent of households with family members working with different community	0.253	0.35	**Livelihood strategies**	**0.384**	**0.508**
Percent of households dependent solely on agriculture as a source of income	0.587	0.813			
Average agricultural livelihood diversification index	0.311	0.36			
Percent of households that do not receive a warning about the pending natural disaster	0.773	0.841	**Natural Disaster and climate variability**	**0.349**	**0.324**
Percent of households with injury or death as a result of recent natural disaster	0.013	0.013			
Average number of flood, drought, bushfires events in the past 6 years	0.304	0.355			
Mean, standard deviation of monthly average minimum daily temperature (years: 1983-2013)	0.134	0.134			
Mean, standard deviation of monthly average maximum daily temperature (years: 1983-2013	0.192	0.192			
Mean, standard deviation of monthly average precipitation (years: 1983-2013)	0.680	0.411			
Average time to health facility (foot)	0.360	0.339	**Health**	**0.410**	**0.338**
Percent of households with family member with chronic illness	0.280	0.267			
Percent of households where a family member had to miss work or school in the past 6 months	0.627	0.680			
Average malaria exposure*prevention index	0.377	0.068			
Overall LVI				**0.346**	**0.312**

Source: Author's computation from field survey (2015)

Water is mostly collected by women and children, due to the short distance to water sources in the communities in both Municipalities it decreases the time burden of household chores and slightly affects time for care in the case of the women and school attendance in the case of the children.

Wenchi Municipality reported a higher percentage (47.62%) of households that do not have a consistent water supply and Techiman had (19.75%).

Due to the availability of pipe and bore holes in both Municipalities, the households are not affected much during the dry season when most natural water sources tend to dry up. More households in the Techiman Municipality reported storing water daily compared to those in the Wenchi Municipality.

The second major component is the socio-demographic profile which consists of five sub-components. Wenchi showed greater vulnerability (0.246) on the socio-demographic profile index than Techiman (0.228). About 37.33% of the household heads in the two Municipalities have no basic education. Formal education tends to improve the ability of smallholder maize farming households to better appreciate issues disturbing them and therefore look for possible solutions at the appropriate places (Etwire *et al.*, 2013). Illiteracy limits smallholder maize farming households' access to information, especially from written sources, thereby increases their susceptibility to climatic stresses.

Techiman Municipality showed greater vulnerability (0.260) on the percent of households with orphans than Wenchi Municipality (0.173). Techiman Municipality showed lesser vulnerability (0.105) on the dependency ratio than Wenchi (0.140). This is due to the fact that the population under 15 and over 65 years, that is the dependent group, are found in the Wenchi Municipality than the Techiman Municipality.

The third major component is the food which consists of five sub components. When all the results of the sub-components were aggregated, Wenchi Municipality was found to be more vulnerable (0.257) than Techiman (0.252). The average number of months, households struggle to find food was the same for the two Municipalities (about 1). Food security improves household's resilience to external stresses including extreme climatic events (World Bank, 2010). This is due to the fact that as individuals, communities and countries get access to good-quality food. They can sell the supplement which will lead to the falling in real prices for food which results to increase in their real incomes. This could motivate them to adapt a climate change strategy (World Bank, 2010).

About 64% of the households in the Wenchi Municipality depend solely on the family farm for food whiles 81.33% of the households in the Techiman Municipality also depend solely on their family farm for food. The average crop diversity index showed that Techiman Municipality was more vulnerable (0.321) than Wenchi Municipality (0.290). Though, based on the index for food as the major component Wenchi Municipality was more vulnerable, it was less vulnerable when it comes to the aspect of the crop diversity. This is attributed to the fact that as the household either work on lease land or rent, in addition to the family land, it facilitates the production of different crops. This will help reduce the households' vulnerability to climate change.

The fourth major component is a social network which consists of three sub-components. When all the sub-components in both Municipalities were aggregated, Wenchi

Municipality was found to be more vulnerable (0.577) in terms of social network than Techiman Municipality (0.516). Households in the Wenchi Municipality were reported to be receiving more help than giving to others compared to Techiman.

Techiman Municipality showed that 93.34% of the households have not been to their local authority for any help while 100% of the households in the Wenchi Municipality did not go to their local authority for any assistance. Most of the respondents prefer seeking assistance from their friends and relatives than their local government Authorities.

The fifth major component is livelihood strategies which consist of three sub-components. When all the sub-component were aggregated, Techiman showed greater vulnerability (0.508) than Wenchi Municipality (0.384). Techiman Municipality showed a greater vulnerability (0.253) on percent of households with family members working in different community than Wenchi (0.35). This signifies that more households have some members working with different community in Wenchi (35%) than Techiman (25.3%).

Techiman Municipality had about 81.27% of the households dependent solely on agriculture as a source of income whiles Wenchi has 58.66%. Techiman showed greater vulnerability (0.360) on average agriculture livelihood activity than Wenchi (0.311). This implies that the households in the Wenchi Municipality practice more diversified agricultural activities compared to Techiman Municipality. This finding also suggests that the lesser agricultural activities a household engage in, the more vulnerable they are to climatic stress. This is due to the fact that as the household diversify their agricultural activities (such as planting different crops or rearing animals with crops), that will enable the household to move to a higher income level which will further facilitate the adoption of a climate change strategy.

The sixth major component is health it consists of four sub-components. When all the sub-components were aggregated, Techiman Municipality showed lesser vulnerability (0.338) than Wenchi (0.410). Wenchi Municipality showed greater vulnerability (0.360) on average time household takes to reach a health facility than Techiman (0.339). Inadequate access to health services tends to decrease the health status of smallholder farming households, thereby increasing their vulnerability to extreme climatic conditions (World Bank, 2010). Wenchi showed a greater vulnerability (0.377) on average malaria exposure*prevention than Techiman (0.068).

Techiman also showed lesser vulnerability (0.267) to household with family members with chronic illness than Wenchi (0.280). On the percentage of households where a family member had to miss school or work in the past 6 months, Techiman showed a greater vulnerability (0.680) than Wenchi (0.627).

The seventh major component is a natural disaster and climate variability, it consists of six sub-components. When all the components were aggregated, Wenchi Municipality showed greater vulnerability (0.349) than Techiman Municipality (0.324). About 77.3% of the households in the Techiman Municipality did not receive a warning about the pending natural disaster. Whiles 84.1% of the households in Wenchi did not receive a warning about the pending natural disaster with an index of 0.773 and 0.841 respectively. On the percentage of households with injury or death as a result of recent natural disaster both Municipalities recorded same (0.013).

Techiman Municipality recorder a greater vulnerability to average number of natural disaster events in the past six years than Wenchi Municipality with index of 0.355 and 0.304 respectively. Both Municipalities recorded same index for mean standard deviation of monthly average minimum and maximum daily temperatures in 30years period, 0.134 and 0.192 respectively.

Indices recorded for Techiman and Wenchi with respect to mean standard deviation of monthly average precipitation (years: 1983-2013) are 0.411 and 0.680 respectively. This implies that Wenchi district showed a greater vulnerability in terms of Mean, standard deviation of monthly average precipitation than Techiman. The overall aggregated LVI for all the major component for both Techiman and Wenchi were 0.312 and 0.346 respectively.

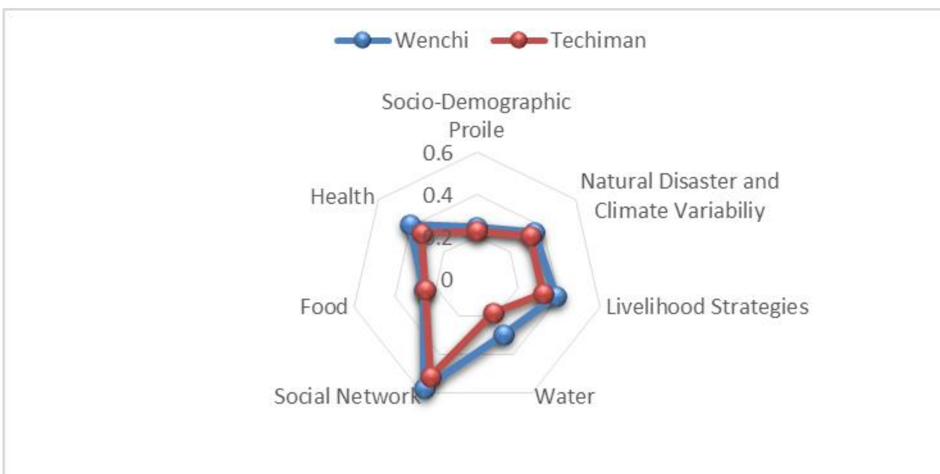

Figure 4.5: Vulnerability spider diagram of the major components of the LVI for Techiman and Wenchi

Source: Author's Computation from Field Survey (2015)

The results of all the major components are summarized in figure 4.5. The vulnerability spider diagram ranges between 0 (least vulnerable) and 0.6 (Extremely vulnerable). Wenchi Municipality was more vulnerable in terms of water, food, health, social-networks and natural disaster and climate change. Techiman Municipality was more vulnerable in terms of livelihood strategies.

Table 4.13: LVI-IPCC contribution calculation for Techiman and Wenchi Municipalities

Contributing factors	Major components	Major component values	Number of sub-component per major component	Contributing factor values	LVI-IPCC value
Adaptive capacity	Socio-demographic profile	0.228 (0.246)	5	0.383(*0.384*)	
	Livelihood strategies	0.508 (0.384)	3		
	Social networks	0.516(0.577)	3		
Sensitivity					
	Health	0.338(0.410)	4	0.252(*0.314*)	
	Food	0.252(0.257)	5		-0.015 (*-0.011*)
	Water	0.183(0.295)	5		
Exposure					
	Natural disasters and climate variability	0.324(0.349)	6	0.324(*0.349*)	

Note: Values in the parenthesis are for Wenchi Municipality

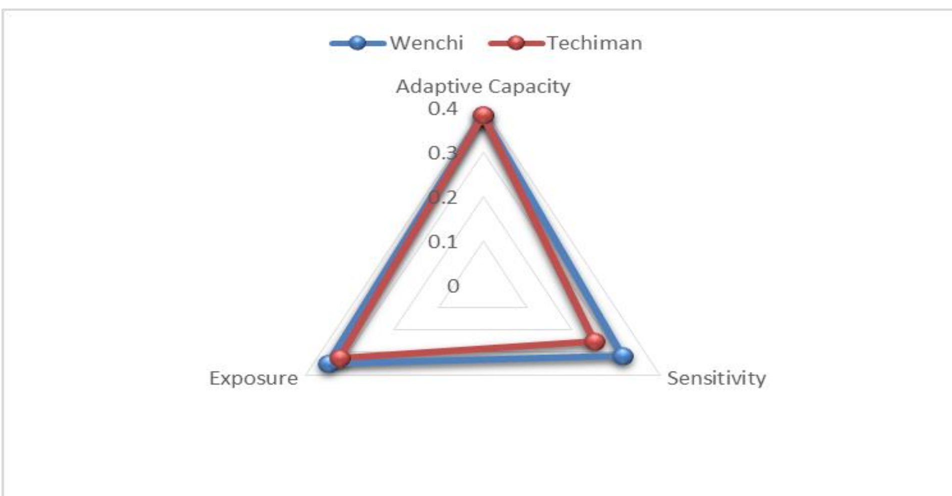

Figure 4.6: Vulnerability Triangle Diagram of LVI-IPCC for Techiman and Wenchi
Source: Computations from field survey, 2015

The LVI-IPCC was computed by grouping the seven major components into three categories, namely, exposure, sensitivity and adaptive capacity. Exposure was made up of the score of only one major component, sensitivity and adaptive capacity were made up of aggregated scores of three major components each. IPCC definition of vulnerability, which takes into account exposure, sensitivity and adaptive capacity is presented in the vulnerability triangle as shown in figure 4.6, it ranges from 0 (low contributing factor) and 0.4 (high contributing factor).

The vulnerability triangle indicates that Wenchi Municipality was more exposed to climate change and variability. Thus, was more sensitive to climate change and variability, taking into consideration the water, health and food status of the households in the Municipality. It was still the most vulnerable in terms of adaptation capacity of households, taking into account the socio-demographic, social networks and livelihoods of households in the Municipality.

The LVI-IPCC estimates for the Techiman and Wenchi Municipalities were -0.015 and -0.011 respectively. This implies that overall, in terms of climate change and variability Wenchi Municipality was more vulnerable than Techiman Municipality.

Table 4.14: Results of Two-Sample T-Test to Test Difference in Mean LVI

Variable	Obs.	Mean	Std. Err	Std. Dev.	T-test	P-value	d.f
Techiman	75	0.358	0.009	0.081			
Wenchi	75	0.329	0.007	0.069	-2.312**	0.022	148
Pooled	150	0.343	0.006	0.077			

**** indicates P<0.05** Source: Author's computation from the field survey (2015)

Table 4.14 depicts the diagnostics of the two-sample t-test. The null hypothesis was rejected because the t-statistics obtained from the simulation was 2.312 which is greater than the value obtain from t statistical table (1.96) with a degree of freedom of 148. This result is also supported by the probability value which is less than 5% (0.05) significance level. This implies that there is a disparity between the mean LVI computed for Techiman and Wenchi Municipalities.

Table 4.15: Results of Two-Sample T-Test to Test Difference in Mean LVI-IPCC

Variable	Obs.	Mean	Std. Err.	Std.Dev.	T-test	P-value	d.f
Wenchi	75	0.035	0.004	0.037			
Techiman	75	-0.047	0.006	0.050	-11.38	0.000***	148
Pooled	150	-0.006	0.005	0.060			

***** indicates P<0.01** Source: Author's computation from field survey (2015)

Table 4.15 depicts the diagnostics of the two-sample t-test. The null hypothesis was rejected because the t-statistics obtained from the simulation was 11.38 which is greater than the value obtain from t statistical table (1.96) with a degree of freedom of 148. This result is also supported by the probability value which is less than 1% (0.01) significance level. This implies that there is a difference between the LVI-IPCC means computed for Techiman and Wenchi Municipalities

4.1.3 Generalized Least Squares Estimation of the Determinants of Smallholder Maize Farming Households' Vulnerability to Climate Change

Before the data analysis, the contingency coefficient test was applied to ascertain whether multicollinearity was present among the independent variables, so that the variables that are highly dependent and strongly correlated to each other can be omitted. The coefficient was scaled as; those within ± 0.499 were said to be weakly correlated and those within ± 0.500 and above were highly correlated. This categorization was employed by Uddin *et al.* (2014) which assessed the factors influencing farmers' adaptation strategies to environmental degradation and climate change effect.

All the independent variables were used in the estimation due to the fact that none of the variables were found to be strongly correlated. The outcomes are presented in the appendix II.

Heteroscedasticity

The study employed the Breusch-Pagan test for heteroscedasticity to ascertain whether or not the models are void of heteroscedasticity. The result is presented in the table 4.18

Table 4.16: Breusch-Pagan Heteroscedasticity Test Results

Sample	Chi (2)	Prob>chi2
Pooled	0.81	0.367
Techiman	0.08	0.776
Wenchi	2.34	0.126

Source: Author's computation from field survey (2015)

The table 4.16 depicts that all the three models have probability values which is greater than 5% (0.05) significance level. This implies that the null hypothesis cannot be rejected and so it can be concluded that the residual error have constant variance. This indicates that all the three models are free from heteroscedasticity.

Omitted Variable Test

The study employed the Ramsey RESET specification-error test for omitted variable to ascertain whether all the three models need additional variables. The result is presented in table 4.17.

Table 4.17: Ramsey RESET Specification Error Test Result

Sample	F (3,131)	Prob>F	F (3,56)	Prob>F
Pooled	1.61	0.189		
Techiman			1.02	0.390
Wenchi			1.41	0.248

Source: Author's computation from the field survey (2015)

Table 4.18 indicates that the probability values of all the three models are all above 5% (0.05) significance level. This indicates that the null hypothesis which states that there is no omitted variable cannot be rejected. This implies that all three models can be used to discuss policy options.

Among the variables included in the generalized least squares regression as shown in table 4.8, the coefficient of gender of household, age of household head, household size, hired labour, family labour, physical asset owned by household, economically active household female members and household annual income were found to be consistent with the *a priori* expectation of the study in all the three models. Although, age of household and household size were hypothesized to be either positive or negative.

For the educational level of household head, though it was consistent with the expected sign of the study in the Wenchi Municipality and the pooled models, it was negated in the model for Techiman Municipality. The expected sign of the farm size was negated in all the three models, as well as farm experience of the household head. For the temperature perception and access to formal credit, the model for Wenchi was consistent with the study's expectation whiles it was violated in Techiman and the pooled models. The coefficient of rainfall precipitation was violated in both Wenchi and the pooled, but was consistent in the Techiman as well as the member of a local social group.

The model for Wenchi revealed that, gender of household head, farm size, rainfall perception and family labour were statistical significant at 5%, 10%, 1%, and 5% respectively.

Table 4.18: GLS Regression Results of the Determinants of Household Vulnerability to Climate Change

Variable	Wenchi		Techiman		Pooled	
	Coef. Robust	P>|Z|	Coef. Robust	P>|Z|	Coef. Robust	P>|Z|
Gender of head	**0.597****	**0.013**	0.007	0.739	**0.036****	**0.016**
Age of household head	-0.001	0.137	-0.001	0.156	**-0.001****	**0.022**
Education of head	-0.008	0.469	0.001	0.902	-0.004	0.600
Household size	0.004	0.206	0.006	0.136	**0.004***	**0.084**
Farm-size	**0.007***	**0.097**	**0.009****	**0.031**	**0.009*****	**0.002**
Temp. Perception	-0.006	0.733	**0.110*****	**0.000**	0.019	0.294
Rain. perception	**0.053*****	**0.002**	**-0.072*****	**0.002**	**0.028***	**0.098**
Household Annual income	-0.000	0.627	-0.000	0.946	-0.000	0.527
Hired labour	-0.016	0.350	**-0.040****	**0.029**	**-0.034*****	**0.008**
Family labour	**-0.010****	**0.028**	**-0.017*****	**0.008**	**-0.011*****	**0.001**
Physical asset of Household	-0.000	0.503	**-0.000*****	**0.003**	**-0.000****	**0.014**
Member of local group	-0.002	0.888	0.019	0.325	0.008	0.501
Access to formal credit	-0.000	0.992	0.018	0.452	0.024	0.129
Economically active Female Household members	0.006	0.311	**0.011*****	**0.007**	**0.008****	**0.026**
Experience of head	0.000	0.994	0.0012	0.159	0.001	0.241
Constant	**0.357*****	**0.000**	**0.349*****	**0.000**	**0.345*****	**0.000**
Diagnostic statistics						
Number of observation		75		75		150
Deviance		0.219		0.352		0.636
Pearson		0.219		0.352		0.636
AIC		-2.572		-2.098		-2.412
BIC		-254.513		-254.380		-670.789
Log pseudo likelihood		112.459		94.665		196.892

*****, **, * denotes 1%, 5% and 10% significant levels respectively**

Source: Author's computation from field survey (2015)

Gender of household head had a significant positive effect on vulnerability to climate change implying that female-headed households are more vulnerable to climate change than their male counterparts.

The empirical result is consistent with Horrell and Krishnan (2007) who found that female headship of a household increase the probability of a household being more vulnerable to climate change. This is due to the fact that females are mostly constrained by lack of access to resources such farm inputs, credit and labour. The empirical result also corroborates the findings by Lambrou & Piana (2006) which reported that women are more vulnerable to climate change due to the fact that they involve in less-labour intensive and subsistence agriculture compared to their to their male counterparts.

Farm size also had a positive statistically significant effect on vulnerability to climate change implying that the larger the size of the farm owned by a household the more vulnerable that household will be to climate change. This result is consistent with Katsushi *et al.* (2015) which reported a negative relationship between farm size and productivity and concluded that households with large farms find it difficult to adopt an improve methods of farming since most strategies come with a cost. The empirical result is also supported by Deininger *et al.* (2013).

Rainfall perception had a positive statistical significant effect on households' vulnerability to climate change. This implies that household that perceives changes in the rainfall amount are more vulnerable to climate change and vice versa. The empirical result is contrary to Deressa *et al.* (2009) which asserted that households that perceive changes in the rainfall amount are more likely to adapt a strategy and so make them less vulnerable to climate change comparatively. The empirical result is consistent with Mandleni and Anim (2011) which reported a negative relationship between temperature perception and adoption of adaptation measures.

A possible explanation of the positive impact of rainfall perception on vulnerability to climate change could be due to the fact that households that perceive changes doesn't adopt a strategy to mitigate the adverse impact of climate change, though this requires further investigation. The implication the empirical result could be that mere perception about temperature change doesn't make a household less vulnerable to climate change unless they are ready to adopt a strategy. The same can be applied to temperature perception.

Family labour had a negative statistically significant influence on vulnerability to climate change. This signifies that household which uses many of the members for their farming activities is less vulnerable to climate change. This result is consistent with Quisumbing (2007) and Peterman *et al.* (2010) which reported a positive relationship between family labour and productivity of staple crops.

The Techiman model also indicates that farm size, temperature perception, rainfall perception, hired labour, family labour, household physical asset owned, and economically active female household members were statistically significant at 5%, 1%, 1%, 5%, 1%, 1%, and 1% respectively.

Farm size had a positive statistically significant effect on vulnerability to climate change. This implies that the larger the farm size of the household, the more vulnerable the household would be to climate change. Similar findings have been reported in Katsushi *et al.* (2015) and Deninger *et al*. (2013) which reported a negative relationship between farm-size and labour intensity. This implies that households with large farm size find it difficult to adapt a strategy since the majority of the strategies are labour intensive.

Rainfall perception had a statistically significant negative effect on vulnerability to climate change, implying that households which perceive that there has been changes in the rainfall amount are less vulnerable than the households which perceive no such change. The empirical result corroborates what Deressa *et al.* (2009) which found households that perceive changes in the rainfall amount are more likely to adapt a climate change adaptation strategy and so make them less vulnerable comparatively.

Temperature perception had a statistically significant positive effect on vulnerability to climate change. This implies that household that perceives changes in the rainfall amount are more vulnerable to climate change, this result did not only violated the studies expected sign but also Deressa *et al.* (2009) but it is consistent with Mandleni and Anim (2011) which observed a negative relationship between temperature perception and adoption of adaptation measures.

Hired labour had a negative significant effect on vulnerability to climate change. This means that households which employ hired labour to supplement the family labour in their farming activities are less vulnerable to climate change than their counterparts who do not employ hired labour. The empirical result is consistent with Mazvimavi *et al*. (2014) which posited that households who employ hired labour in their farming activities are able to increase crop production, thereby rendering them less vulnerable to climate change compared to their counterparts which depend solely on their family labour.

Family labour had a significant negative influence on households' vulnerability to climate change. The empirical result indicates that households who source majority of its labour from their families for their farming activities are less vulnerable to climate change than their counterparts that use less family labour in their activities. The empirical result is consistent with Quisumbing (2007) and Peterman *et al.* (2010) which reported a positive relationship between family labour and productivity of staple crops.

Physical asset of the household had a negative significant effect on vulnerability to climate change. This implies that the more physical asset a household owns, the less vulnerable it will be to climate change and vice versa. This result was expected because the study believes that if a household possess more physical asset, some can be liquidated to buy inputs such as improved seed varieties and fertilizer that will increase their crop production levels and increase their resilience to climate change. This result is consistent with the findings of Mazvimavi *et al*., (2014) and Perz (2005).

Economically active female household members had a positive statistically significant effect on vulnerability to climate change, implying that households with more economically active female members than their male counterparts are more vulnerable to climate change than the households with less economically active female members than their male counterparts. This result was expected by the study because it is believed that females are mostly constrained by lack of access to resources such farm inputs, credit and the energy to undertake diverse on-farm and off-farm activities compared to their male counterparts. The empirical result is consistent with (Horrell and Krishnan, 2007).

The empirical results from the pooled model revealed that, gender of household head, age of household head, household size, farm size, rainfall perception, hired labour, family labour, household physical asset owned and economically active female household members were statistically significant at 5%, 5%, 10%, 1%, 10%, 1%, 1%, 5%, and 5% levels respectively.

Gender of household had a significant positive effect on households' vulnerability to climate change, meaning that female-headed households are more vulnerable to climate change than their male counterparts; this also affirms the findings of Horrell and Krishnan (2007).

Age of household head also had a negative significant effect on vulnerability to climate change, meaning that as the age of a household head increase by one year it leads to the decrease in the level of vulnerability of that household to climate change. This relationship was expected because the aged households' head are believed to be more resourced that will facilitate the adoption of strategies pertaining to climate change than their young counterparts. The empirical result is consistent with the findings of Bayard *et al. (*2007).

Household size had a positive significant effect on vulnerability, implying the larger the household size, the more vulnerable it is to climate change. The empirical result is consistent with Widyanti *et al*. (2010) which revealed that the larger the household size the higher is the dependency ratio which increases that household's vulnerability to climate change.

Farm size exhibited a positive relationship with smallholder maize farming households' vulnerability to climate change. The result implies that the larger the size of the farm owned by a household the more vulnerable that household would be to climate change. This is due to that fact that household with large farm finds it difficult to adapt a strategy since the majority of the strategies are labor intensive and it comes with a cost. The empirical result is consistent with Katsushi *et al*. (2015) and Deninger *et al.* (2013) as well as Peterman *et al.* (2010) which reported an inverse relationship between farm area and productivity.

Rainfall perception also had a positive significant effect on vulnerability, implying that household that perceives some changes in the rainfall amount are more vulnerable to climate change. This result is contrary to Deressa *et al.* (2009) who found that such households are able to adopt a strategy than their counterparts. However, the empirical result is consistent with Mandleni and Anim (2011) which reported a negative relationship between temperature perception and adoption of adaptation measures.

Hired labour had a negative statistically significant effect on vulnerability to climate change. This implies that households who are able to employ hired labour for their farming activities are less vulnerable to climate change than their counterparts which are unable or do not employ hired labour for their farming activities. The empirical result corroborates with Mazvimavi *et al*. (2014).

Family labour also had a negative significant effect on households' vulnerability to climate change, implying that households with more members to be employed as labour for their off-farm and on-farm activities are less vulnerable to climate change comparatively. The empirical result agrees with Quisumbing (2007) and Peterman *et al.* (2010).

Physical asset owned by household had a negative significant effect on vulnerability to climate change. This implies that the more physical asset a household possesses the less vulnerable it will be to climate change. The empirical result is consistent with Perz (2005) which asserted that households with physical asset are able to diversify their livelihood activities and so makes them less vulnerable to climate change comparatively.

Economically active female household members had a statistically significant positive effect on vulnerability to climate change. This implies that households that have more of it economically active members being female are more vulnerable to climate change comparatively. This is due to the fact that females are constrained in terms of access to credit and other inputs. The empirical result is consistent with (Horrell and Krishnan, 2007).

4.1.4 Assessing the Constraints to Climate Change Adaptation Strategies

In this section constraints were identified from literature, pre-tested and were presented to the respondents to rank from the most pressing (1) to the least pressing (7). They include, lack of access to credit, lack of ready market for produce, poor extension service, lack of access to meteorological information, lack of access to improved crop varieties, lack of education on climate change, Lack of climate change adaptation policy. The result is presented in table 4.19.

Table 4.19 indicates that for the pooled sample, the Kendall's rank technique showed that lack of access to credit, lack of ready market for produce, and poor extension service were the three most pressing constraints identified by the respondents with mean scores 2.01, 2.85 and 3.48 respectively.

This result agrees with studies such as (Peterson *et al.*, 2013; Antwi-Agyei *et al.,* 2013) which reported that financial constraint is one of the key barriers to climate change adaptation strategies by smallholder farming households.

Table 4.19: Constraints to Climate Change Adaptation Strategies

Constraints	Techiman		Wenchi		Pooled	
	Mean Score	**Rank**	**Mean Score**	**Rank**	**Mean Score**	**Rank**
Lack of access to credit	2.25	1st	1.77	1st	2.01	1st
Lack of ready market for produce	3.45	3rd	2.24	2nd	2.85	2nd
Poor extension service	2.61	2nd	4.35	4th	3.48	3rd
Lack of access to meteorological information	3.49	4th	4.28	3rd	3.88	4th
Lack of access to improved crop varieties	5.06	5th	4.83	5th	4.94	5th
Lack of education on climate change	5.67	6th	5.02	6th	5.35	6th
Lack of climate change adaptation policy	5.46	7th	5.51	7th	5.48	7th
Diagnostic statistics						
Number of Observation	75		75		150	
Kendall's W	0.414		0.438		0.374	
Chi-square calculated	**186.377**		**197.012**		**336.414**	
Chi-square critical	**12.5916**		**12.5916**		**12.5916**	
Degree of Freedom	6		6		6	
Asymptotic sig.	0.000		0.000		0.000	

Source: Author's computation from field survey (2015)

The empirical result also agrees with Vermeulen *et al.* (2012) who found that lack of ready market for produce is one of the main constraints militating against smallholder farming households in their quest to adopt climate change adaptation strategy. Vermeulen *et al.* (2012) also found that due to lack of storage facilities smallholder farming households accept whatever price they are offered. The result again is consistent with Antwi-Agyei et al. (2013) which posited that poor extension service is one of the main constraints to climate change adaptation strategy in the Sub-Saharan Africa.

Kendall's W was 0.374 meaning there is 37.4% agreement among the rankers of the constraints. The chi-square (χ^2) calculated from the simulation was 336.414 and the chi-square (χ^2) obtained from the statistical table with 5% (0.05) significant level and 6 degrees of freedom was 12.5916. Since the chi-square (χ^2) calculated from the Kendall's concordance simulation is greater than the chi-square (χ^2) obtained from the statistical table, the null hypothesis was rejected meaning there is an agreement among the rankers of the constraints. The result was supported by the probability value of 0.000 which less than 1% significant levels.

For the Techiman Municipality, the Kendall's rank technique result exhibited that lack of access to credit, poor extension service and lack of ready market for produce were the three most pressing constraints identified by the respondents with mean scores 2.25, 2.61 and 3.45 respectively.

Kendall's W was 0.414 meaning there is 41.4 % agreement among the rankers of the constraints. The chi-square (χ^2) calculated from the simulation was 186.377 and the chi-square (χ^2) obtained from the statistical table with 5% (0.05) significant level and 6 degrees of freedom was 12.5916. Since the chi-square (χ^2) calculated from the Kendall's concordance technique is greater than the chi-square (χ^2) obtained from the statistical table, the null hypothesis was rejected meaning there is an agreement among the rankers of the constraints. The result was supported by the probability value of 0.000 which less than 1% significant levels.

For the Wenchi Municipality, the Kendall's rank technique exhibited that access to credit, lack of a ready market for produce and lack of access to meteorological information were the three most pressing constraints identified by the respondents with mean scores 1.77, 2.24 and 4.28 respectively. The empirical result corroborates Adger *et al.* (2009) which opined that information and awareness on climate change is one of the principal constraints to adaptation strategies of smallholder farming households.

Kendall's W was 0.438 meaning there is 43.8 % agreement among the rankers of the constraints. The chi-square (χ^2) calculated from the simulation was 197.012 and the chi-square (χ^2) obtained from the statistical table with 5% (0.05) significant level and 6 degrees of freedom was 12.5916. Since the chi-square (χ^2) calculated from the Kendall's concordance technique is greater than the chi-square (χ^2) obtained from the statistical table, the null hypothesis was rejected meaning there is an agreement among the rankers of the constraints. The result was supported by the probability value of 0.000 which is less than 1% significant level.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents the summary, main conclusions, policy recommendations and directions for future research based on the findings of the study.

5.2 Summary and Conclusions of the Study

Kasperson *et al*. (2003) posits that vulnerability has no commonly accepted definition, due to the fact that different institutions use the term differently to explain their areas of concern.

The IPCC (2007) defines climate change vulnerability as the level to which a system is liable, or incapable to survive under adverse effects of climate change, including climate variability and extremes. This assertion also concluded that climate change vulnerability is a function of the character, extent and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Past empirical studies show that smallholder maize farming households are vulnerable to climate change.

This study uses data from household level to analyse vulnerability to climate change, the determinants of their vulnerability level and the constraint to climate change adaptation strategies. A total of 150 respondents were enumerated in two Municipalities in the Brong-Ahafo region of Ghana. Seventy five (75) smallholder maize farming households were enumerated for each of the Municipality. Two communities were sampled from each Municipality. The livelihood vulnerability index was computed for each household to ascertain their vulnerability levels of climate change through the use of 31 key indicators.

Generalized least squares model was used to determine household vulnerability. The constraint to climate change adaptation strategies was analyzed using Kendall's ranking technique.

Finally the socio-economic characteristics of the respondents were also explained. These characteristics included age of the household head, gender of household head, household size, experience of the household and others.

The results show that majority (73.33%) of the respondents in the Wenchi Municipality perceived an increase in the temperature intensity whereas 9.33% perceived a decrease over 30years. In the Techiman Municipality majority (69.33%) of the respondents perceived an increase in temperature intensity whereas 21.33% perceived a decrease over 30 years. In the pooled estimation majority (71.33%) of the respondents perceived an increase in temperature intensity whereas 15.33% perceived a decrease over 30 years.

The study again showed that 37.33% of the respondents in the Wenchi Municipality perceived a decrease in the rainfall amount whereas 33.33% perceived an increase over 30years. In the Techiman Municipality majority (54.67%) of the respondents perceived a decrease in the rainfall whereas 37.33% perceived an increase over 30 years. In the pooled, 46% of the respondents perceived a decrease in the rainfall amount whereas 35.33% perceived an increase over 30 years.

The findings from the study suggest that the majority (44%) of the maize farming households in the Wenchi Municipality were moderately vulnerable to climate change. For the Techiman, majority (34.7%) of the smallholder maize farming households were highly vulnerable to climate change and in the pooled sample, majority (38.7 %) of the smallholder maize farming households were moderately vulnerable to climate change to climate. The two-sample t-tests results indicate that there was difference in the means between the LVIs and LVI-IPCC computed for Techiman and Wenchi Municipalities.

The empirical results revealed that Wenchi Municipality was more vulnerable to the major components such as water, food, natural disaster and climate variability, social network, health and socio-demographic profile whiles Techiman Municipality was more vulnerable in terms of livelihood strategies. The overall LVI computed from the major components indicate that Wenchi Municipality was more vulnerable with an index of 0.346 compared to that of Techiman Municipality with 0.312. The LVI-IPCC index computed also indicates that Wenchi Municipality was more vulnerable than Techiman i.e. -0.011 and -0.015 respectively.

The GLS estimation results for the pooled sample showed that, gender of household head, age of head, household size, farm-size, hired labour, family labour, physical asset owned by household, rainfall perception and economically active female household members are the important factors explaining smallholder maize farming household's vulnerability to climate change.

For Techiman, farm size, temperature perception, hired labour, family labour, physical asset and economically active female household members were the important factors explaining smallholder maize farming households' vulnerability to climate change whiles in the Wenchi Municipality, gender of household head, farm size, rainfall perception and family labour are the important factors explaining smallholder maize farming households' vulnerability to climate change.

The study showed that the three most pressing constraints facing smallholder maize farming households' climate change adaptation strategy in the Techiman Municipality were; lack of access to credit, poor extension service and lack of a ready market for produce, whereas that of Wenchi Municipality were lack of access to credit, lack of a ready market for produce, lack of access to meteorological information. Whiles the pooled sample indicated that, lack of access to credit, lack of a ready market for produce, poor extension service were the three most pressing constraints militating against the smallholder maize farming households' adaptation to climate change with mean scores of 2.01, 2.85 and 3.48 respectively.

5.3 Recommendation of the Study

The results from study indicate that climate change is being experienced in the Brong-Ahafo region of Ghana, and maize farming households are being adversely affected by this phenomenon.

The study provides the following recommendations.

First, Wenchi Municipality should be given priority by both government and donors in terms of distribution of income generating and food security projects in order to reduce the farming households' vulnerability to food. This is based on the result that Wenchi was more vulnerable in terms of food for the maize farming households.

Second, there is the need to improve water supply in the Wenchi Municipality using such measures as construction of more boreholes in to reduce the time taken to fetch water source and to reduce conflicts over water. This recommendation is based on the result that Wenchi Municipality was more vulnerable in terms of water which also had higher respondents reporting on water conflicts.

Third, there is need to build more community health centers in the Wenchi Municipality in order to reduce the time taken to reach a health facility. This recommendation is based on the result that Wenchi Municipality was more vulnerable in terms of health.

Fourth, it is recommended that sustainable livelihood options (example, making of handicrafts and food processing) and social protection programs in the Techiman Municipality are introduced in order to improve livelihoods. This is based on the empirical results that Techiman Municipality was more vulnerable in terms of livelihood strategies.

Fifth, the Municipal Assemblies and Meteorological Agencies as well as other Non-governmental Organizations (NGOs) should inform smallholder maize farming households in the Techiman and Wenchi Municipalities about impending natural disasters such as floods, droughts, pests among others. This is based on the empirical results that majority of the respondents in both Municipalities did not receive warning about impending disasters.

Sixth, Government should revamp its financial institutions to encourage the disbursement of credit to smallholder maize farming households in the Techiman and Wenchi Municipalities. This will encourage the households to diversify their agricultural activities or adopt climate change strategies. This will enable the smallholder farming households to become resilient to climatic shocks. The recommendation is based on the empirical results showing that lack of access to credit is an important constraint to climate adaptation strategies by the smallholder maize farming households in both Municipalities.

5.4 Direction for Future Research

It is expected that the findings of this research will encourage further research interest employing the Livelihood Vulnerability Index to compute the vulnerability status of households to climate change in all the Regions in Ghana. It is again expected that future research employs an econometric method to assess the vulnerability status of households to climate change.

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APPENDICES

Appendix I

UNIVERSITY OF GHANA; DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS, LEGON

This study is being carried out by Derick Taylor Adu, a graduate student of the University of Ghana, Legon, on the topic **Smallholder maize farming households' vulnerability to climate change in the Brong-Ahafo Region of Ghana**, in partial fulfillment of the award of master of philosophy in Agricultural Economics. All information gathered will be treated with much confidentiality and would solely be for academic purposes. Your support and contribution would be very much appreciated. For further enquiries, please contact me at adutaylorderick49@gmail.com or call 0208504120/0548040959.

A. GENERAL INFORMATION

1. Household Code: [………………]

2. Name of the respondent: [………………………………]

3. Sex of the respondent: [………]   1 = Female   0 = Male

4. Age of the respondent: [……………]

5. Highest level of formal education of respondent: [……….]
   0 = None   1 = Basic (Primary/JHS/Middle)   2 = Secondary (Secondary/Vocational)
   3 = Tertiary (Training college/Polytechnic/University)

6. Marital status of respondent: [………..]
   0 = Single   1 = Married   2 = Divorced/Separated   3 = Widowed

7. Years of experience of farming of respondent: […………]

8. Is the respondent the head of the household? (If man is away > 6months/yr, then woman is head)? […………] 1 = Yes 0 = No **If yes, skip to question 14**

9. If no, provide the name of the head […………]

10. Sex of the head: [………….]   1 = Female 0 = Male

11. Age of head: […………]

12. Highest level of formal education of head: […………]
0 = None 1 = Basic (Primary/JHS/Middle) 2 = Secondary (Secondary/Vocational)
3 = Tertiary (Training college/Polytechnic/University)

13. Marital status of head: […………..]
0 = Single 1 = Married 2 = Divorced/Separated 3 = Widowed

14. Household head' years of experience of farming: [……………]

15. Does the respondent belongs to any social group? 1 = Yes 0 = No

B. ASSETS

Q	16. **Household assets owned –** Circle the items the household owns and provide the current value or amount paid			
		Item	**Number**	**Number**
	1	Radio	…………………	Cedis……………
	2	Television	…………………	Cedis……………
	3	Mobile Phone	…………………	Cedis…………....
	4	Bicycle	……………………	Cedis……………
	5	Refrigerator	……………………	Cedis……………
	Animals owned – Provide the approximate number the farms owned of each type of live animal.			
		Cattle	…………………	Cedis…………..
		Draft animals (oxen, donkeys, horses etc.)	…………….....	Cedis……………
		Poultry	………………....	Cedis……………
		Rabbits	………………..	Cedis……………
		Sheep	…………………	Cedis……………
		Goats	…………………	Cedis……………
		pigs	…………………	Cedis……………
		Fish (estimate number)	…………………	Cedis……………
		Beehives	………………	Cedis……………
		Others (Please specify)	…………………	Cedis…………

C. HOUSEHOLD COMPOSITION

17. How many persons are in this household? Total: [……..] Male: [……] Female: […...]

18. How many are orphaned (< 15 and have lost one or both parents)? [………..]

19. Number of persons with ages below 15 years. Total: [….] Males: [….] Females: […..]

20. Number of persons between ages of 15 and 65 years. Total: [...] Males: [...] Females: [...]

21. Number of persons with ages above 65 years. Total: [….] Males: [….] Female: […..]

D. HOUSEHOLD INCOME SOURCES

22. What is the main occupation of the head of the household? [….] 1 = Agriculture

2 = Professional/administrative 3 = Production and related works 4 = Service 5 = Student

6 = Others (please Specify): ……………………………………………………

23. Is any member of the household engaged in any off-farm income generating activities?

[……] 1 = Yes 0 = No, if no, skip to 24.

24. If yes, please provide the details below

Activity	Number of females	Number of males
Petty trading		
Handicrafts making		
Gathering something form the wild or water bodies		
Timber processing		
Small scale mining		
Others (please specify)		

25. Household total annual income

Write the initials of every household member	Gender	If the person worked in the previous year, how much did he/she earned

E. AVAILABILITY AND ACCESS TO INFRASTRUCTURE

26. Does any member of your household work outside this community? [……..] 1 = Yes 0 = No

27. What is the main source of water for drinking and for household chores? […….] 1 = Pipe borne 2 = Dam 3 = Rain 4 = River, lake, stream 5 = Wells 6 = borehole 7 = others (please specify): ……………………………………………………………

28. How long (in minutes) does it take to get to the water source on foot? [………….]

29. How long (in minutes) does it take to get to the water source on bicycle? [………..]

30. Has water availability been a problem? […………..] 1 = Yes 0 = No

31. Estimate the number of buckets (Size 34) of water stored everyday (Probe)………

32. In the past, have you heard about any conflicts over water in this community? [......] 1 = Yes 0 = No

33. How long in (minutes) does it take to get to a health facility on foot? […………]

34. How long in (minutes) does it take to get to a health facility by bicycle? [………]

35. Do any of the household members have a chronic illness? [……..] 1 = Yes 0 = No

36. Has any member of the household been very ill in the past 6 months that they had to miss work or school? […….] 1 = Yes 0 = No

37. How many months in a year is malaria particularly common? [……………….]

38. Name the months: 1 = Jan/2=Feb/……12=Dec […………………………………]

39. How many mosquito nets does the household have? [………………]

F. FARM CHARACTERISTICS

40. What is your total farm size (hectares)? [………………..]

41. What crops did you cultivate last season (2013)?	42. Area cultivated (hectares)	43. Harvest of this crop per planting season (100kg)	44. Percentage consumed	45. Percentage sold	46. Total value of crops harvested (GH₵)

47. Does this household save seeds to cultivate in the next planting season/year? […………]

    1= Yes 0 = No

48. Does your household have adequate food throughout the year? 1 = Yes 0 = No

49. If no, how many months in a year does this household experience food shortage [………]

50. Where does your household get most of its food? 1 = Own farm 2 = Purchases 3 = Relative (s) 4 = Others (Please specify): ....

51. Did any member of your household hired labour in any economic activity? 1 = Yes 0 = No

52. In the last production year, how many household members were actively involved in the household enterprise? [………..]

53. Name the months: Jan=1 Feb =2……, Dec = 12 […………………………………]

G. ACCESS TO CREDIT

54. Has any member of this household received any assistance from relatives or friends within the past 12 months (e.g. remittances, care during sickness or medicines, sale of crops or livestock, baby-sitting etc.)? […………] 1 = Yes 0 = No **if no, skip to 56**
55. List the assistance given:

a) …………………………………………. (c) ……………………………………

(b) …………………………………………. (d) …………………………………..

56. Did you borrow any money from relatives/friends in the past 12 months? [ ] 1 = Yes

0 = No if no, skip to 58

57. What did you use it for? [……………………………………………………………..]

58. Did you borrow any money from formal credit sources in the past 12 months? [……] 1 = Yes

0 = No if no, skip to 60

59. What did you use it for? [……………………………………………………….]

60. Did you lend any money to relatives/friends in the past 12 months? [ ] 1=Yes 0 = No

61. In the past 12 months, has any member of your household gone to your community leader for help (e.g., Chief, Assemblyman, Member of parliament etc.)? [………..] 1 = Yes 0 = No

62. If yes specify the type of help received? [……………………………………………]

H. CLIMATE CHANGE

63. Have you noticed any changes in the weather pattern in the past 30years? [……….]

1 = Yes 0 = No

64. If yes, what notable changes have been observed?

(a) ……………………………………………………………………………………

(b) ………………………………………………… (c) ………………………………

65. What changes have been observed in the temperature pattern?

1 = consistent 2 = Do not understand 3 = Decreased 4 = Increased

66. What changes have been observed in the rainfall pattern?

1 = consistent 2 = Do not understand 3 = Decreased 4 = Increased

67. Has your household suffered from any drought or flood since 2000? [……..] 1 = Yes 0 = No,

If no skip to 73

68. Did you receive any warning about the flood or drought before it happened? […….] 1 = Yes 0 = No

69. Did any member of your household sustain any injury or lost their life as a result of the flood or drought [……] 1 = Yes 0 = No

70. If yes, indicate the number that got injured [.........]/ passed away [……..]

71. Did you lose any livestock as a result of the flood or drought? [……] 1 = Yes 0 = No

72. Was there any loss in the value of your livestock as a result of the flood or drought? […...]

1 = Yes 0 = No

I. CONSTRAINTS TO CLIMATE CHANGE ADAPTATION STRATEGIES

73. Rank the following constraints to climate change and variability adaptation strategies from the most pressing to the least pressing using the numbers 1,2,3…..7

Constraints	Rank (1 most and 7 least constraining)
Poor extension service	
Lack of access to meteorological information	
Lack of climate change adaptation policy	
Lack of access to credit	
Lack of ready market for produce	
Access to improved crop varieties	
Lack of education on climate change	

J. ACCESS TO AGRICULTURAL EXTENSION SERVICE

74**.** Have you received any extension services form other farmers in the past 12 months? [……]

1 = Yes 0 = No

75. Have you received any formal agricultural extension service in the past 12 months? [……]
1 = Yes 0 = No
76. If Yes, what are the services (Multiple response): [ ]/ [ ]/ [ ] [ ]

Codes: 1 = Establishment of demonstration farm 2 = Organization of field days 3 = Awareness creation 4 = Facilitates access to input 5 = Facilitates access to credit 6 = Advice on crop management 7 = introduced new varieties 8 = others (please specify)
…………………………………………………………………………………………

77. Would you like to add any other information?

…………………………………………………………………………………………
………………………………………………………………………………………...

THANKS FOR YOUR CO-OPERATION

Appendix II
Major component and sub-component of livelihood vulnerability

Major component	Sub-component	Explanation of sub-component
Socio-demographic profile	Dependency ratio	Ratio of the population under 15 and over 65 years of age to the population between 19 and 65 years of age
	Percent of households where the primary adult is a female	Percentage of households where the primary adult is female. If a man is away from home more than 6 months per year the female is counted as the head of the household.
	Percent of households where head of household has not attended school	Percentage of households where the head of the household reports that they have attended 0 years of school
	Percent of households with orphans	Percentage of households that have at least 1 orphan living in their home. Orphans are children less than 18 years old who have lost one or both parents
Livelihood strategies	Percent of households with family member working in a different community	Percentage of households that report at least 1 family member who works outside of the community for their primary work activity.
	Percent of households dependent solely on agriculture as a source of income	Percentage of households that report only agriculture as a source of income
	Average Agricultural Livelihood Diversification index (range: 0.20-1)	The inverse of (the number of agricultural livelihood activities+1) reported by a household.
Health	Average time to health facility (minutes)	Average time it takes the households to the nearest health facility
	Percent of households with family member with chronic illness	Percentage of households that report at least 1 family member with chronic illness.
	Percent of households where a family member had to miss work or school in the last two 2 weeks due to illness	Percentage of households that report at least 1 family member who had to miss school or work due to illness in the last 2
	Average Malaria Exposure*Prevention Index	Months reported exposure to malaria*Owning at least one bednet
Social network	Average receive : Give ratio	Ratio (the number of types of help received by a household in the past month+1) to (the number of types of help given by a household to someone else in the past month+1)
	Average Borrow : Lend Money ratio	Ratio of a household borrowing money in the past month to a household lending money in the past
	Percent of households that have not gone to their local government for assistance in the past 12 months	Percentage of households that reported that they have not asked their local government for any assistance in the past 12 months
Food	Percent of households dependent on	Percentage of households that get their food primarily from their personal

	family farm for food	farms.
	Average number of months households struggle to find food	Average number of months households struggle to obtain food for their family.
	Average crop diversity index	The inverse of (the number of crops grown by a household+1)
	Percent of households that do not save crops	Percentage of households that do not save crop from each harvest
	Percent of households that do not save seeds	Percentage of households that do not save seeds from year to year
Water	Percent of households reporting water conflicts	Percentage of households that report having heard about conflicts over water in their community
	Percent of households that utilize a natural water source	Percent of households that report a river, stream lake, pool and hole
	Average time to water source (minutes)	Average time it takes the households to travel to their primary water source
	Percentage of households that do not have a consistent water supply	Percentage of households that report that water is not available at their primary water source everyday
	Inverse of the average number of liters of water stored per household	The inverse of (the average numbers of liters of water stored by each household+1)
Natural disasters and climate variability	Average number of flood, bushfires, drought, and cyclone events in the past 6 years	Total number of floods, bushfires, droughts, and cyclones that were reported by households in the past 6 years
	Percent of households that did not receive a warning about the pending natural disasters	Percentage of households that did not receive warning about the severe flood, bushfires, drought, and cyclone even in the past 6 years
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years	Percentage of households that reported either an injury to or death of one of their family members as a result of the most severe flood, drought, or cyclone in the past 6 years
	Mean standard deviation of the daily average maximum temperature by month	Standard deviation of the average daily maximum temperature by month between 1983 and 2003 was averaged for each Municipality
	Mean standard deviation of the daily average minimum temperature by month	Standard deviation of the average daily minimum temperature by month between 1983 and 2003 was averaged for each Municipality
	Mean standard deviation of average precipitation by month	Standard deviation of the average monthly precipitation between 1983 and 2003 was averaged for each Municipality

LVI sub-component values and minimum and maximum sub-components for Techiman and Wenchi Municipalities

Major component	Sub-component	WEN.	TECH.	Max for Both	Min. for Both
Water	Percent of household reporting water conflict	41.95	9.770	100	0
	Percent of households that utilize a natural water source	14.67	1.13	100	0
	Average time to water source	10	6	45	0
	Percent of household that do not have a consistent water supply	47.62	19.97	100	0
	Inverse of the average number of liters of water stored per household	0.120	0.119	0.500	0.030
Socio-Demographic	Dependency ratio	0.350	0.732	7	0
	Percent of female headed household	18.1	29.33	100	0
	Average age of female-headed households	0.020	0.020	0.050	0.004
	Percent of households where head has not attended school	28.9	23.0	100	0
	Percent of household with orphans	17.34	26.00	0.257	0.252
Food	Percent of households dependent solely on family farm for food	64.00	81.3	100	0
	Average number of months households struggle to find food	1.19	1.00	8	0
	Average crop diversity index	0.290	0.321	1.00	0.170
	Percent of households that do not save seeds	4.00	4.00	100	0
	Percent of households that do not save crops	9.34	13.00	100	0
Social-network	Average Receive : Give ratio	1.23	1.49	4.00	0.50
	Average Borrow : Lend	1.16	1.33	3.00	0.50
	Percentage of household that have not gone to their local government for assistance in the past 12 months	100	93.3	100	0
Livelihood strategies	Percent of households with family member working in different community	25.30	35.00	100	0
	Percent of households dependent solely on agriculture as a source of income	58.7	81.27	100	0
	Average agricultural livelihood diversification index	0.480	0.52	1	0.25
Natural Disaster	Percent of households that do not receive a warning about the pending natural disaster	77.3	84.1	100	0
	Percent of households with injury or death as a result of recent natural disaster	1.30	1.30	100	0
	Average number of flood, drought, bushfires events in the past 6 years	3.65	4.61	13	0
	Mean standard deviation of monthly average minimum daily temperature (years:1988-2013)	1.91	1.19	10.99	0.5
	Mean standard deviation of monthly average maximum daily temperature (years:1988-2013	4.24	4.24	14.06	1.91
	Mean standard deviation of monthly average precipitation (years: 1983-2013)	77.53	77.66	122.09	13.12
Health	Average time to health facility (foot)	73.87	19.31	180	1
	Percent of households with family member with chronic illness	28.00	26.70	100	1
	Percent of households where a family member had to miss work or school in the past 6 months	62.7	68.01	100	1
	Average malaria exposure*prevention index	1.51	0.27	4	0

Indexed Sub-components, major component for Natural disaster and climate variability and overall LVI for the pooled (Brong-Ahafo Region)

Components	Sub-component	units	Observed value or index	Max. value	Min. value	VI
Water	Percent of household reporting water conflict	Percent	25.86	100	0	0.259
	Percent of households that utilize a natural water source	percent	7.900	100	0	0.079
	Average time to water source	Minute	8	45	0	0.178
	Percent of household that do not have a consistent water supply	percent	33.795	100	0	0.338
	Inverse of the average number of liters of water stored per household	1/liters	0.360	0.500	0.020	0.206
	Water Vulnerability					**0.312**
Socio-Demographic	Dependency ratio	Ratio	0.790	7	0	0.113
	Percent of female headed household	Percent	22.555	100	0	0.226
	Average age of female-headed households	1/Years	0.010	0.05	0.004	0.130
	Percent of households where head has not attended school	percent	37.33	100	0	0.373
	Percent of household with orphans	percent	21.67	100	0	0.217
	Socio-demographic vulnerability					**0.212**
Food	Percent of households dependent solely on family farm for food	percent	72.67	100	0	0.727
	Average number of months households struggle to find food	Months	1.07	8	0	0.134
	Average crop diversity index	1/crop	0.300	1	0.170	0.160
	Percent of households that do not save seeds	percent	8	100	0	0.080
	Percent of households that do not save crops	percent	22.34	100	0	0.223
	Food vulnerability					**0.264**
Social-Network	Average Receive : Give ratio	ratio	1.36	4	0.5	0.250
	Average Borrow : Lend	Ratio	1.24	3	0.5	0.300
	Percentage of household that have not gone to their local government for assistance in the past 12 months	Percent	96.67	100	0	0.967
	Social-Network Vulnerability					**0.503**
Livelihood Strategies	Percent of households with family member working in different community	Percent	30.16	100	0	0.302
	Percent of households dependent solely on agriculture as a source of income	Percent	75.635	100	0	0.756
	Average agricultural livelihood diversification index	ivelihoods	0.5	1	0.25	0.33
	Livelihood Strategies Vulnerability					**0.464**
Natural Disaster	Percent of households that do not receive a warning about the pending natural disaster	Percent	80.705	100	0	0.817
	Percent of households with injury or death as a result of recent natural disaster	Percent	1.33	100	0	0.013
	Average number of flood, drought, bushfires events in the past 6 years	count	4.13	13	0	0.318

	Mean standard deviation of monthly average minimum daily temperature (years:1988-2013)	Celsius	1.91	10.99	0.5	0.134
	Mean standard deviation of monthly average maximum daily temperature (years:1988-2013	Celsius	4.24	14.06	1.91	0.192
	Mean standard deviation of monthly average precipitation (years: 1983-2013)	Millimeters	77.595	122.09	13.12	0.595
	Natural Disaster Vulnerability					**0.343**
Health	Average time to health facility (foot)	Minute	19.31	180	1	0.102
	Percent of households with family member with chronic illness	Percent	27.335	100	0	0.273
	Percent of households where a family member had to miss work or school in the past 6 months	Percent	65.34	100	0	0.653
	Average malaria exposure*prevention index	Months*Bed net indicator	1.313	4	0	0.328
	Health Vulnerability					**0.339**
OVERALL LVI						**0.331**
LVI-IPCC						**-0.005**

Calculating the food component for the LVI for Techiman Municipality

Sub-component for food major component	Sub-component values	Max. sub-component value for study population	Min. sub-component value for study population	Index value for Techiman	Food major component value for Techiman
Percent of households dependent on family farm for food (F1)	81.33	100	0	0.813	0.252
Average number of months households struggle to find food (range: 0-12) (F2)	1	8	0	0.125	
Crop diversity index (range: 0- 1)* (F3)	0.321	1	0.200	0.150	
Percent of households that do not save crops (F4)	13	100	0	0.130	
Percent of households that do not save seeds (F5)	4	100	0	0.040	

Step 1 (Repeat for all sub-component indicators): $Index_{Food1Techiman} = \frac{81.33 - 0}{100 - 0} = 0.813$

Step 2 (Repeat for all major components): $Food_{Techiman} = \frac{\sum_{i=1}^{n} index_{sm^i}}{n} =$

$$\frac{F_1 Techiman + F_2 Techiman + F_3 Techiman + F_4 Techiman + F_5 Tec\,himan}{n}$$

$$= \frac{0.813 + 0.125 + 0.150 + 0.130 + 0.040}{5} = 0.252$$

Step 3 (Repeat for all study areas): $LVI_{Techiman} = \frac{\sum_{i=1}^{7} w_{Mi} M_{mi}}{\sum_{i=1}^{7} wM_i}$

$$= \frac{(5)(0.183) + (5)(0.228) + (5)(0.252) + (3)(0.516) + (3)(0.508) + (6)(0.324) + (4)(0.338)}{5 + 5 + 5 + 3 + 6 + 4 + 3} = 0.312$$

Calculating LVI-IPCC for Techiman Municipality

Contributing factors	Major components	Major component values	Number of sub-component per major component	Contributing factor values	LVI-IPCC value
Adaptive capacity	Socio-demographic profile	0.228	5	0.383	
	Livelihood strategies	0.508	3		
	Social networks	0.516	3		
Sensitivity					
	Health	0.338	4	0.252	
	Food	0.252	5		**-0.015**
	Water	0.183	5		
Exposure					
	Natural disasters and climate variability	0.324	6	0.324	

Step 1 (Calculated indexed sub-component indicators and major components as shown in Appendix IV, taking the inverse of the adaptive capacity sub-component indicators: Socio-demographic Profile, Livelihood strategies, and Social Networks).

Step 2 (Repeat for all contributing factors: exposure, sensitivity, and adaptive capacity):

$$AdaptiveCapacity_{Techiman} = \frac{\sum_{i=1}^{7} w_{Mi} M_{mi}}{\sum_{i=1}^{7} wM_i} = \frac{(5)(0.228)+(3)(0.508)+(3)(0.516)}{5+3+3} = 0.383$$

Step 3 (Repeat for all study areas): $LVI - IPCC_{Techiman} = (e_{Techiman} - a_{Techiman}) * s_{Techiman}$

$$= (0.324 - 0.383) * 0.252 = -0.015$$

Contingency coefficient test for co-linearity between independent variables (Pooled sample)

Variable	GEN	AGE	EDU	EXP	PASS	HSIZ	HMEM	FARM	FOC
GEN	1								
AGE	-0.176	1							
EDU	0.158	-0.243	1						
EXP	-0.087	-0.071	0.210	1					
PASS	-0.0667	-0.079	0.006	-0.074	1				
HSIZ	0.221	-0.236	0.027	0.008	0.019	1			
HMEM	-0.063	-0.024	0.026	0.042	-0.190	-0.1180	1		
FARM	0.424	-0.059	0.114	-0.093	-0.207	0.100	0.275	1	
FOC	-0.007	-0.139	0.154	0.057	0.251	0.053	-0.164	-0.352	1
TEMP	0.061	0.010	0.032	0.060	-0.186	-0.089	-0.017	0.140	-0.116
RAIN	-0.092	0.035	0.129	-0.097	0.170	-0.073	0.021	-0.277	0.073
MLSG	-0.029	-0.197	0.063	0.132	0.161	0.214	-0.190	-0.208	0.096
HAI	-0.419	-0.029	-0.173	0.264	0.079	-0.096	0.152	-0.077	0.063
HLAB	0.382	-0.196	0.071	0.005	0.100	0.145	0.011	0.012	0.097
FLAB	-0.135	0.226	-0.004	-0.056	0.0413	-0.079	-0.417	-0.247	0.108
_CONS	-0.248	-0.448	-0.357	0.156	0.078	-0.007	0.027	-0.119	-0.007

VARIABLE	TEMP	RAIN	MLSG	HAI	HLAB	FLAB	_CONS
TEMP	1						
RAIN	-0.067	1					
MSLG	-0.053	-0.113	1				
HAI	-0.091	0.139	0.087	1			
HLAB	-0.108	0.167	-0.089	-0.122	1		
FLAB	0.085	0.028	-0.080	-0.040	-0.101	1	
_CONS	-0.278	-0.044	0.071	0.215	-0.303	-0.105	1

Contingency coefficient test for co-linearity between independent variables (Techiman Sample)

Variable	GEN	AGE	EDU	EXP	PASS	HSIZ	HMEM	FARM	FOC
GEN	1								
AGE	-0.318	1							
EDU	0.049	-0.466	1						
EXP	-0.095	-0.064	0.358	1					
PASS	-0.054	-0.070	0.333	-0.419	1				
HSIZ	0.233	-0.194	0.122	-0.252	0.253	1			
HMEM	-0.020	-0.332	0.229	0.309	0.042	-0.074	1		
FARM	0.431	-0.328	0.060	0.128	-0.007	-0.113	0.438	1	
FOC	0.179	-0.141	0.228	-0.042	0.131	0204	-0.336	-435	1
TEMP	-0.236	0.192	-0.020	-0.150	0.072	0.164	0.218	-0.074	-0.445
RAIN	0.165	-0.116	0.242	0.005	0.123	0.045	-0.299	-0.222	0.056
MLSG	0.054	-0.134	0.159	-0.017	0.271	0.405	-0.197	-0.225	0.307
HAI	-0.485	0.071	-0.023	0.255	-0.159	-0.029	0.129	-0.072	0.101
HLAB	0.250	-0.006	0.118	-0.291	0.363	0.349	-0.083	-0.176	0.132
FLAB	-0.109	0.300	-0.192	0.090	-0.306	-0.087	-0.372	-0.060	0.040
_CONS	-0.100	-0.053	-0.106	0.276	0.037	-0.073	0.291	0.219	-0.219

VARIABLE	TEMP	RAIN	MSLG	HAI	HLAB	FLAB	_CONS
TEMP	1						
RAIN	-0.406	1					
MSLG	-0.169	0.318	1				
HAI	0.134	-0.037	0.022	1			
HLAB	0.233	-0.005	0.015	-0.080	1		
FLAB	-0.299	0.123	-0.286	-0.088	-0.256	1	
_CONS	-0.145	-0.421	-0.162	0.097	-0.278	-0.134	1

Source: Author's computation from field survey (2015)

Contingency coefficient test for co-linearity between independent variables (Wenchi sample)

Variable	GEN	AGE	EDU	EXP	PASS	HSIZ	HMEM	FARM	FOC
GEN	1								
AGE	0.075	1							
EDU	0.122	0.018	1						
EXP	0.071	-0.079	0.087	1					
PASS	-0.024	-0.169	-0.292	0.136	1				
HSIZ	0.253	-0.039	0.009	0.245	0.115	1			
HMEM	-0.104	0.054	0.071	-0.326	-0.249	-0.309	1		
FARM	0.147	-0.028	0.289	-0.025	-0.068	-0.057	0.247	1	
FOC	0.071	0.070	0.226	-0.080	-0.357	-0.155	0.247	0.291	1
TEMP	0.056	-0.282	-0.046	0.259	-0.242	-0.143	-0.055	0.173	0.120
RAIN	-0.014	0.0180	0.163	-0.158	0.115	-0.136	0.115	-0.073	-0.130
MLSG	-0.291	-0.281	-0.076	0.288	0.163	0.022	-0.208	-0.128	-0.191
HAI	0.215	0.054	-0.087	-0.296	0.117	0.298	-0.194	-0.402	-0.064
HLAB	0.293	-0.387	-0.011	0.260	0.129	-0.144	0.043	0.0794	-0.124
FLAB	-0.180	0.015	-0.085	-0.143	0.076	-0.737	-0.158	-0.206	0.053
_CONS	-0.051	-0.059	-0.421	0.226	0.221	-0.189	0.060	-0.186	-0.116

VARIABLE	TEMP	RAIN	MSLG	HAI	HLAB	FLAB	_CONS
TEMP	1						
RAIN	-0.425	1					
MSLG	-0.110	-0.309	1				
HAI	-0.100	-0.326	-0.138	1			
HLAB	-0.032	0.302	0.019	-0.401	1		
FLAB	0.241	0.077	-0.128	-0.116	-0.020	1	
_CONS	-0.030	-0.102	0.402	-0.371	-0.055	0.089	1

Source: Author's computation from the field survey (2015)

Two-Sample T-Test to Test Difference in Mean of LVI Major Components

Variable	Obs.	Mean	Std. Err	Std. Dev.	T-test	P-value	d.f
Water							
Techiman	75	0.188	0.014	0.124			
Wenchi	75	0.388	0.021	0.181	7.930***	0.000	148
Combined	150	0.288	0.015	0.184			
Livelihood strategies							
Techiman	75	0.478	0.019	0.165			
Wenchi	75	0.577	0.018	0.161	3 .686***	0.000	148
Combined	150	0.528	0.139	0.170			
Health							
Techiman	75	0.040	0.001	0.012	45.551***	0.000	148
Wenchi	75	0.617	0.013	0.109			
Combined	150	0.328	0.024	0.300			
Food							
Techiman	75	0.133	0.002	0.016	-41.616	0.000	148
Wenchi	75	0.040	0.001	0.012			
Combined	150	0.086	0.004	0.049			
Natural Disaster							
Techiman	75	0.327	0.006	0.053	2.499***	0.006	148
Wenchi	75	0.349	0.007	0.057			
Combined	150	0.338	0.005	0.056			
Socio-Economic							
Techiman	75	0.360	0.014	0.125	-3.779***	0.000	148
Wenchi	75	0.284	0.014	0.123			
Combined	150	0.322	0.011	0.130			
Social Network							
Techiman	75	0.617	0.013	0.109	-9.251***	0.000	148
Wenchi	75	0.247	0.038	0.329			
Combined	150	0.432	0.025	0.307			

*** indicates <0.001