PERCEPTIONS AND ADAPTATION STRATEGIES OF RICE FARMERS TO CLIMATE CHANGE IN ADAKLU DISTRICT, GHANA

BY

ERIC MENSAH

(10598992)

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

DEPARTMENT OF AGRICULTURAL ECONOMICS & AGRIBUSINESS

SCHOOL OF AGRICULTURE

COLLEGE OF BASIC AND APPLIED SCIENCES

UNIVERSITY OF GHANA, LEGON

(JULY 2018)

DECLARATION

I, Eric Mensah, the author of this thesis **"Perceptions and Adaptation Strategies of Rice Farmers to Climate Change in Adaklu District, Ghana",** do hereby declare that apart from the references to other people's work which I have duly acknowledged and of which a plagiarism report is attached in appendix IV, 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.

...

Eric Mensah

(Student)

Date: ....

This thesis has been submitted with our approval as supervisors**.**

Prof. Ramatu M. Al-Hassan	Dr. AKwasi Mensah Bonsu
………………………………..	……………………………..
(Major Supervisor)	(Co-Supervisor)
Date:	Date:................................

DEDICATION

I dedicate this work to my uncle Mr. Philip Agyei-Twum and my siblings Mr. Paul Kwabena Appiagyei Mensah and Mr. Anthony Kwaku Obour.

ACKNOWLEDGEMENTS

In the course of undertaking this study, I have received support from many people to whom I wish to register my appreciations. But first and foremost, I want to thank Almighty God, who by his steadfast love and mercy, has seen me through this course.

Secondly, I would like to register my sincere appreciation to my supervisors, Professor Ramatu M. Al-Hassan and Dr. Akwasi Mensah-Bonsu, both Department of Agricultural Economics and Agribusiness: University of Ghana, Legon, for their tolerance, tireless efforts, guidance and encouragement throughout the whole period of preparation and execution of the research.

I express my sincere appreciation to the Head of Department of Agricultural Economics and Agribusiness, Dr Irene Egyir for her immense contribution towards this study. My deepest gratitude also goes to every one of the lecturers, staff and students of the Department of Agricultural Economics and Agribusiness.

This work will not have been possible without the support of my uncle Mr. Philip Agyei-Twum and my siblings, especially Mr Paul Kwabena Appiagyei Mensah, Mr Anthony Kwaku Obour, Mr. Francis Kwame Owusu. Some special thanks go to my mother, Madam Catharine Agyei and sisters Felicia Owusu and Cecilia Owusu for their support and prayers.

I will not forget the special contribution made by Dr. Yaw Osei-Asare, Dr. John B. D. Jatoe both senior lecturers Department of Agricultural Economics and Agribusiness, Mr. Enoch Kwaku Armah, Mr. Emile Mawutor Tsekpo, Mr Divine Agbegoe, and Mr. Felix Yao Akpabli for their contribution without which this study would have remained a day dream.

ABSTRACT

Climate variability is one of the great challenges facing smallholder farmers in Ghana and more specifically rice farmers. The main objective of this study was to assess the perceptions and adaptation strategies of rice farmers to climate change in Adaklu district. Specifically, the study sought to, i) determines rice farmers' perceptions of climate change; ii) estimate the adaptive capacities of rice farmers to climate change; iii) identify the adaptation strategies used by rice farmers and iv) identify the determinants of number of adaptation strategies used by a rice farmer in the district. Primary data were collected using structured questionnaires and focus group discussions whereas secondary data on climate variables was collected from the Ghana Meteorological Agency. Twenty-five respondents each were sampled from five communities, making 125 respondents. Descriptive statistics, semi-logarithm regression and Poisson regression methods were used in analysing the objectives. The adaptive capacities of farmers were also estimated and categorized into high, moderate and low adaptive capacities. The results indicate that, (84%) of the farmers perceive decreased in rainfall, 13% perceived unpredictability of rainfall, (2%) sees no change in rainfall and (0.8%) say rainfall has been increasing over the years. With respect to temperature, majority of respondents (98%) perceived increased in temperature, whiles (0.8%) perceived unpredictability and no change in temperature. The perception of farmers was consistent with the estimated rising trend and decreasing trend in temperature and rainfall. On the average, rice farmers in Adaklu district were found to be moderately adaptive to climate change. Rice farmers were found to be adopting eleven strategies to mitigate the impacts of climate change on their farm. The dominant strategy was changing planting date (97.6%), planting early maturing varieties (73.6%), and using chemical or organic fertilizer (68.8%). The results of the Poisson regression show gender, education, access to credit, farm income, farming experience and awareness of climate change to be factors that statistically influence the adoption of number of adaptation strategies. Agricultural extension services should be improved to help in educating farmers on adaptation strategies that are more climate smart and sustainable. Informal and non-formal education through information centres and lessons for adult farmers should be encouraged. Farmers are aware of changes in climate and associated risk. Although they respond to the risks with a number of strategies, their capacity to adapt is only moderate. Access to early maturing rice varieties by farmers must be enhanced for rice farmers to fully adapt to climate variability in the study area.

TABLE OF CONTENT

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

ABREVIATIONS

AGRA- Alliance for Green Revolution in Africa

CRI- Crop Research Institute

CSIR- Council for Scientific and Industrial Research

GMA-Ghana Meteorological Agency

PHC- Population and Housing Census

MoFA- Ministry of Food and Agriculture

GSS- Ghana Statistical Service

NBM- Negative Binomial Model

IRR- Incidence Rate Ratio

PCRM- Poisson Count Regression Module

PCM- Poisson Regression Module

NRDS- National Rice Development Strategy

CARD- Coalition for African Rice Development

IPCC-Intergovernmental Panel on Climate Change

UNFCCC- United Nations Framework Convention on Climate Change

GDP- Gross Domestic Product

ISSER- Institute of Statistical Social and Economic Research

COP- Conference of Parties

IFPRI-International Food Policy Research Institute

WMO- World Meteorological Organisation

MESTI- Ministry of Environment Science Technology and Innovation

NCCP- National Climate Change Policy

MEST- Ministry of Environment Science and Technology

FANPARN- Food, Agriculture, and Natural Resource Policy Analysis Network

UNTC- United Nation Treaty Collection

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Climate change refers to a change in the state of weather condition which can be identified by changes in the average and or the fluctuations of its compositions which may persist for a longer period of time, typically decades or longer (IPCC, 2014). Climate change poses challenges on the economy, environment and the society and it has become a global issue (Scholze *et al*., 2006). Initially, climate change studies were more focused on human undertakings that have altered the conformation of the worldwide atmosphere (UNFCCC, 1992). However, climate change studies are now focused on variability in climate variables, compared to long-term average values (IPCC, 2014).

Agricultural activity affects climate change and climate change also impacts agriculture. Climate change in Ghana poses challenges on the environment, economy and the society, mostly in rural communities whose source of revenue depends mainly on rain-fed agriculture. Climate change is of much concern to all countries and is of interest to scientists and politicians (Stephens, 1991). The effects of climate change on every continent and nation paved the way for the adoption of the Paris agreement in 2015 (Sutter *et al.*, 2015). A total of 195 UNFCCC member states has signed the agreement with 179 becoming a party to it (UNTC, 2018). This agreement is to deal with the emissions of greenhouse gases, mitigation, financing and adaptation (UNFCCC, 2015).

Climate change or variability, mitigation and adaptation problems have now become an issue of international discussion in the post-industrial revolution when climate variability was observed. Climate change impacts could be reduced now through proper adaptation plans with appropriate mitigation policies implemented to lessen its influences in the future.

Adaptation refers to taking a lead through adjustments in all natural and human systems with an anticipation of a projected climate change (Adger *et al*. 2003). UNFCCC (2007), defines adaptation as a procedure by which societies equip themselves to be able to manage an unknown future against climate change by adjusting and modifying to decrease its harmful impacts. According to these two definitions of adaptation, adjustments by societies must take into consideration the current climatic situations in order to predict the future climatic events to take measures that will better the lives of the society now and the future. The smallholder farmer's ability to adjust, change or improve their method of farming by adopting new technology or innovations to combat the changing climate is the way to better their income, livelihood and reduced vulnerability.

Because of weak structures and institutions of developing countries, climate change adaptation should focus on a regional or local level rather than global measures (Adger *et al*., 2003). This was also the view of Rynikiewic *et al*. (2006), that poor countries are more susceptible due to socioeconomic factors and heavy dependence on primary industries which limit their adaptive capacities. One of the most recently used definitions of adaptive capacity is the capacity of systems, organisations, individuals and other organisms to modify likely harm and take advantage of opportunities (IPCC, 2014). When a system is exposed and sensitive to external stress, that system becomes vulnerable, hence the need to adapt to variations in the socioecological systems. The only way to handle climate change and its associated risk is through the enhancement of adaptive capacity.

Vulnerability reduces through improvement of adaptive capacity and encourages sustainable development (Smit, *et al*., 2000). Smit & Wandel (2006), posit that adaptive capacity to climate modification is contextual and location-based. A farmer's adaptation is determined by their perception that climate has changed and as such their local knowledge and perception should be considered. The way in which people experience climatic shocks differs from one person to the other and also by geographical locations and seasons. A person's perception is based on nature and the environmental factors which may vary depending on the extent of conceiving such perception.

Agriculture will be influenced by climate fluctuations for a very long time globally based on scientific evidence (Nellemann, *et al*., 2009). The output of crops is likely to fall in the tropical and subtropical regions by 10% to 20% between 2020-2050 because of increased negative effects of climate change (Thornton, *et al*., 2014).

In Africa, climate change issues require urgent attention, because a third of Africa‘s population are already residing in drought-prone areas and climate change and variability poses danger to the livelihood and lives of 75 to 250 million people (Fleshman, 2007). This could intensify economic hardship on the continent. Livelihoods, for this reason, will be put in jeopardy. According to the IPCC (2007), the impacts would be experienced differently across the continent because of other socioeconomic challenges.

Though climate variation is not a new phenomenon, it continues to strongly impact agriculture in sub-Sahara Africa, where the agricultural sector is reliant on rainfall and is most susceptible to the negative effects of climate variability. The

Ghanaian economy mainly depends on agriculture and it is mainly subsistence with some commercial farming with the forest, transitional zone and the coastal savannah being the three-major food-producing agro-ecological zones (MoFA, 2016). Agriculture contributes immensely to the Ghanaian economy; its share of GDP of the economy was about 20% in 2015 and 2016 (MoFA, 2016; ISSER, 2017). This share has declined since its higher in earlier years in 2009. The leading sector of the Ghanaian economy in terms of employment is agriculture, employing 44.7% of the active labour force. The Service and Industrial sectors employ 40.9% and 14.4%, respectively (GSS, 2014 as cited in MoFA, 2016). This means, agriculture has regained its position as the largest employer, after dropping second to the service sector, as reported from the 2010 population census (GSS, 2012). The agricultural sector is confronted by many issues of which flood and drought are the major ones, despite its numerous contributions to the Ghanaian economy.

Agricultural production and climate change have been of central focus to world leaders and researchers because of the direct susceptibility of the sector to climate variability. Climate change affects all facets of agriculture, including crop production, livestock, poultry, fisheries production, soil flora, and fauna. The increase in yearly climate variations and the changing factors of production will affect farmers' income, food security and higher food prices to consumers (Molua, 2002).

The unfavourable effects of climate change on countries in the tropical region, including Ghana are frequent drought, diseases infestation, loss of household properties, increased biodiversity loss, loss of wildlife, increased rural-urban relocation, changes in the vegetation type, decrease in soil nutrients and moisture, increased health risk and changing livelihood systems (Railly *et al.*, 2000).

Several assessments conducted locally (Dazé, 2007, Owusu *et al.,* 2008,) and internationally (Maddison, 2006) indicate the vulnerability of Ghanaian agriculture and food system because of its high reliance on rain-fed production and natural resources, and limited capacity of farmers to deal with climate variability. Rice production in Ghana has been increasing due to partnerships between the government and her development partners to boost domestic production to decrease imports of rice. The annual area under rice cultivation has increased from 181,000ha in 2010 to 236,000ha in 2016 (ISSER, 2017). Production has also been increasing except in 2007 when the output level dropped to 185,300MT, from 250,000MT in 2006. It started picking up recording 301,900MT in 2009, 604,040MT in 2014 and 641,492MT in 2015 (MoFA, 2016).

The second most consumed staple food of many Ghanaians after maize is rice. Its consumption has been growing because of urbanization, fluctuations in consumer habit and population growth (MoFA, 2009). Per capita, rice consumption in Ghana increased from 17.5 kg per year from 1999 to 2001 to 22.6 kg per year from 2002 to 2004. It reached 38 kg by 2011 and it was projected to reach 63 kg per year in 2015 (MoFA, 2009), but between 2015 and 2016 per capita consumption of rice was only 32.0 kg (MoFA, 2016). The importation of rice to meet the local demand is alarming. Ghana imported 620,811MT of rice valued at $285.32 million in 2015 (MoFa, 2016) and $300 million worth of rice in 2016 which is 650,000 MT (USDA, 2017). Rice also account for 58 percent of cereal imports (Osei-Asare, 2010). This situation has gotten the attention of the central government, and other development partners in the country.

The production of rice has contributed much to Ghana's capability in achieving food security even though most urban dwellers consume imported rice (Mabe *et al.*, 2013). Ghana has the vegetation cover to support the production of this grain in the country. Ghana, a member of the Coalition for African Rice Development (CARD), launched its National Rice Development Strategy (NRDS) in 2008. The main mandate of NRDS was to increase domestic production by doubling production in 2018 (which implies an annual production growth of 10%) and improving quality to stimulate demand for domestic rice (MoFA, 2009). The French government, through Agence Française De Development, has been developing lowlands and valleys in Volta and the Northern regions through the Rice Sector Support Programme (RSSP). The main objective is to develop 6,000 ha of lowlands and valleys to support domestic rice production to lower the country's burden of importing rice (MoFA, 2011a). The Ghanaian government over the years has intensified the campaign of increasing domestic rice production, mostly in the Northern region, Upper East region and the Volta region, which are the three regions that possess the vegetation cover to produce rice.

The production of rice in the Volta region has been instrumental to the achievement of food security in the region. Volta region has edged the Northern region to become the leading rice producing region in Ghana based on a three-year average from 2013 to 2015 for the first time. It contributed 30% to the overall national output with Northern Region coming second (MoFA, 2016).

The total agricultural land in Ghana is 13,600,00Ha with 6,241,450Ha under cultivation. Out of the total land under cultivation, only 221,000Ha is irrigated representing 3.54% of the total land under cultivation (MoFA, 2016). This makes agricultural production mainly rain-fed, intensifying the need for more irrigation infrastructure. Lack of investment in irrigation infrastructure in the Volta Region means that rice farmers remain vulnerable to the variability of climate. More so, the incidence of crop failure has influenced farmers to the use of fewer inputs and low-risk technologies, making farmers incapable of achieving high yields during favourable seasons (Acquah, 2011).

1.2 Problem Statement

Climate is a key factor inducing agricultural production whose variations largely affect the status of food security. Crop simulation models by IFPRI show that crop yield, such as rice will reduce by 15%, maize by 10% and wheat by 22% by 2050 in Sub-Saharan Africa (IFPRI, 2009). The World Bank reported that three climate variables has been recognised in Ghana and these are changes in temperature and precipitation, and sea level rise (World Bank, 2010). Also, Owusu *et al*. (2008), posit that there is an alteration in the rainfall pattern in Ghana towards a lengthier dry period and disappearing short dry spells.

Decreasing the impacts of climate change requires appropriate responses from farmers, which depend on their perceptions and how they adapt. Smallholder farmers' ability to perceive that the climate has changed is a significant requirement for their choice of adaptation strategies. Maddison (2006), reported that adaptation to climate variability needs farmers to be aware of changes in climate and adopting measures to reduce the effects associated with it. In order to increase policy towards the solution of the problems climate change and variability pose to farmers, it is significant to have information on farmers' perceptions of climate change and choice of adaptation methods. Schipper and Pelling (2006), report that climate change and variability will increase the existing susceptibilities of farmers, because of their poverty status, high dependence on natural resources, the sensitivity of their geographical location and limited ability to adopt new livelihood strategies.

Climate variability has made rice farmers in the Volta region more vulnerable since most of the farms and livelihoods of farmers mainly depend on rain-fed agriculture. It has been reported by Amikuzuno ,2001, Angelucci *et al*., 2013 that, climate change affects the output of rainfed rice farmers more than irrigated farmers in Ghana. According to Kranjac-Berisavljevic *et al.* (2003), water scarcity, rising input cost, inadequate suitable varieties and rain dependency are the most important factors impacting rice production in the country. Smallholder farmers have significant local knowledge in dealing with climate variability during a difficult period, but their traditional coping strategies are outside the realm of managing an unprecedented and sustained high level of variability (Pettengell, 2010). The Agricultural sector has the poorest occupational group in Ghana with food crop farmers being the worst group affected by climate variability (MoFA, 2011b). This is making the sector a major target for both food security and interventions aiming at decreasing poverty in the country.

Even though there have been few studies undertaken on rice farmers' perceptions and adaptation strategies to climate change in the Volta region (Kolleh *et al.*, 2018 and Nhamo *et al.,* 2014), adaptation strategies are location and situation specific. What might work in one place might not be feasible in another place. Different ecological zones, climate, assumption and socioeconomic factors might influence the design of adaptation strategies (IPCC, 2001). Therefore, there is the need to plan adaptation policies that best suit the local circumstances.

Models and climate information are available at macro levels, but little has been done at the micro level (Etwire *et al.,* 2013). Yet, the influence of climate variability is felt at the household level. There has virtually not been any study conducted in the district concerning rice farmers' perceptions and adaptation strategies to climate change despite the importance of these in climate change studies.

Therefore, this study seeks to fill the gap in the literature by using household data to analyse rice farmers' perceptions and adaptation strategies in combating climate change in the Adaklu district. Thus, the research questions are:

1. What is rice farmers' perception of climate change in the study area?
2. What is the level of adaptive capacities of rice farmers in the study area?
3. What are the adaptation strategies used by rice farmers in the study area?
4. What are the factors that influence the number of adaptation strategies?

1.3 Objectives of the Study

The main objective of this study is to assess rice farmers' perceptions and adaptation strategies to climate change in Adaklu district, Ghana.

The specific objectives are to:

1. Determine rice farmers' perceptions of climate change in the study area
2. Estimate the level of adaptive capacities of rice farmers in the study area
3. Identify the adaptation strategies used by rice farmers in the study area
4. Identify the determinants of the number of adaptation strategies

1.4 Justification

Many developing economies, including those in sub-Sahara Africa, depend mainly on agriculture. The sector contributes immensely to employment creation, especially in the rural areas, foreign exchange earnings, and income generation among others. Due to these numerous benefits and more, there is the need for the agricultural sector to be well developed through adequate investments and the protection of the sector against both internal and external factors that threaten the sector to ensure sustainable improvement in production. The study will provide an in-depth analysis of rice farmers' perceptions about, and adaptation strategies to, climate change in the Volta Region.

The study is, thus, aimed at revealing how climate change affects rice yield and how to reduce the level of vulnerability faced by rice farmers. It will offer insight into how farmers are adapting to climate change and the potency of the adaptive strategies that rice farmers adapt to reduce the issue of climate alteration.

The presence of commercial players in the Volta region has contributed to an increase in demand for paddy and this has created a competitive price for paddy in the region. Rice farming has become lucrative in the region and is expanding every year. This source of rice farmers' livelihoods needs to be protected and this research will contribute to the provision of more empirical evidence on the perception of rice farmers to climate change, adaptation strategies adopted, their adaptive capacity, and the determinants of the number of adaptation strategies rice farmers engaged to fight climate change.

This research would also aid in formulating policies to enhance a sustainable agriculture in the district and the entire nation. It will again provide first-hand information to the understanding of the main issues contributing to climate vulnerability among rice farmers in the community, district and regional levels.

Additionally, this study will serve as a reference point for future research into the similar field of study. Therefore, the information offered here will be available for the relevant ministries and development agencies, research and educational institutions and the private sector investors. This research could be extended to assess the effectiveness of the strategies adopted in enhancing rice yields and incomes.

It will also guide researchers, extension agents, policy makers and non-governmental organisations on how to design interventions to meet the needs of rice farmers to mitigate climate change and practice sustainable agriculture.

1.5 Organisation of the thesis

The thesis is organized into five main chapters, which include chapter one, the introduction to the study. Chapter two reviews the literature on concepts of climate change and vulnerability, the perception of farmers to climate change, the concept of adaptation to weather risk and capacities to adapt to climate change. This is followed by chapter three which presents the methodology adopted for the study, touching on issues such as data description and definition, the profile of the area under study and model specifications. Chapter four presents and discusses the results. The summary, conclusions and policy implications of the findings and suggestions for future research are presented in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents reviewed literature, terms and concepts related to climate change, vulnerability, evidence of climate change in Ghana, perception theory and perception of farmers on climate change, empirical findings on adaptive capacity for climate change, concepts of adaptation to climate change, adaptation strategies to climate change, impacts and evidence of climate variability in Ghana. The review also covers the adoption of adaptation strategies.

2.2 Concept of Climate Change

This section deals with definitions of key terminologies which are vital for the understanding of climate change.

The (IPCC, 2014) defined climate as the mean weather conditions or the statistical description of the fluctuation and averages of the composition of the weather over a period of time, usually from months to thousands of years. According to the World Meteorological Organisation (WMO), the best period to effectively assess the climate of an area is three decades. Any change in weather over time and or as a result of human activities. The (UNFCCC), defined it as a change which occurs as a result of the activities of mankind that alters the nature of the atmosphere in addition to fluctuations detected over a period of time. Therefore, climate change is caused by human interaction mainly caused by human activities which have altered the climate variables. This is known as global warming. Scientific research uses theoretical models and observation to understand the past and future climate. The rise in the earth and ocean surface temperature as compared to past centuries is called global warming (De Chavez *et al.*, 2008). The IPCC (2007), also defined climate change as a change in the composition of the climate that can be recognised by changes in the average levels of its properties, and which persist for a long time, usually decades or longer. The main causes of climate change are greenhouse gas emission and trapping. It has caused and still causing the melting of the glaciers, extinction of some animal and plant species, depletion of the coral reefs, increased in the spread of diseases, famine, changes in rainfall pattern, increased in temperature, drought, flood, increase in erosion, etc.

Climate variability refers to fluctuations in the average state and other statistical data about the climate on all temporal and spatial scales beyond that of individual weather events. Climate variability can either be internally or externally caused. Internal variability is caused by inner processes that are inside the climate system while external variability is caused by fluctuations in anthropogenic forces. (IPCC, 2001).

2.2.1 Evidence of climate change in Ghana

Historical climatic data from 1961 to 2000 in Ghana has shown a gradual upsurge in temperature and a decline in mean annual rainfall in all the ecological zones in the country. Evidence of climate change in Ghana is in the form of a rising sea level, declining precipitation, rising temperature and increase in weather related disasters (MESTI, 2016). This confirms the World Bank report that there is an existence of climate variability in the form of temperature change, change in precipitation and a rise in sea level in Ghana (World Bank, 2010). The report also projected that temperature trends in Ghana between 2010 to 2050 will be increasing all over the country with the maximum temperature recordings in the Northern Region. Rainfall readings were higher in the 1960s but have decreased since 1970s and 1980s and are still in the decreasing trend, according to climate data (World Bank, 2010). Analysis of climate data by Owusu *et al.* (2009), shows that rainfall has been decreasing in all ecological zones in Ghana. They further argue that variation in rainfall is the sole indicator of climate change and it is affecting all the ecological zones in the country. Christenssen *et al.* (2007), use the general circulation model (GCM) simulation by Hewitson and Crane (2006), to draw up empirical downscaling and predict drought all around the centre of the Sahel and wetter areas along the Gulf of Guinea.

According to OECD (2011), by the year 2100, an increase of 1mm of sea level will cause 1000km^2 loss of land due to flooding; arable land and livelihood will be affected by shoreline recession; 132,000 people living on the east coast of Ghana will be affected. They further anticipated that movement of people from the coastal area into the hinterlands will be increased due to flooding and land loss. It is expected to cause an estimated loss of $4.8 million by 2020 rising to $5.7 million per annum by 2030.

Ghana experienced flood events in 1960, 1991, 1995 and 2007. In 2007 the worst event being in 2007. In all, 6,000 farms were destroyed, 56 people killed and 330,000 people were affected in diverse ways (United Nations, 2007)

A report by MESTI (2016), predicted that the mean annual temperature will rise in all ecological zones in Ghana by 0.6°C, 1.02°C, 2.0°C and 3.9°C for the year 2020, 2040, 2050, and 2080 respectively with precipitation declining by 1.1% to 20.5%. A research by Cameron (2011), established that rainfall has been reducing and varying with a rise in temperature in all the ecological zones in Ghana over the next 20 years. The Ghana Agricultural News Digest (2012), reported that climate variability is affecting the country's natural resources mostly water and vegetation cover. This is projected to have substantial impacts on resource-dependent sectors (agriculture).

The National Climate Change Policy (NCCP), a Ghanaian response to Climate Change has also documented evidence and incidence of climate change in Ghana. Climate change has manifested in the form of increasing temperature, rainfall variability, which includes unforeseeable climate-related disasters, sea level rise and rise in greenhouse gas emission and dropping of carbon sinks (MEST, 2012).

2.3 Concept of Vulnerability

The IPCC (2007), defines vulnerability to climate extreme events as the level by which a system is unable to survive under negative effects of climate change, as well as fluctuations and excesses whiles Tuner *et al.* (2003), defines it as the level of a system to be harmed due to exposure. The IPCC (2007) and Adger (2006), also conclude that vulnerability is the composition of the atmosphere, extent and amount of climate fluctuations to which a system is exposed, its sensitivity, and adaptability. Timmermann (1981), posits that vulnerability is a wide subject and care must be taken when describing it with the present events unless it is used in a rhetorical manner; but Liverman (1990), notes that vulnerability has been associated with concepts such as resilience, susceptibility and adaptability.

The level to which a community or a system is directly influenced by climate variability is known as exposure to climate change. This includes the various facets of the economy, including agriculture, water system, health and etc. Houses near the high-water mark may be experiencing flooding due to rise in sea level caused by the melting of glaciers and excessive rainfall.

Communities become sensitive to climate change due to its negative effect. This sensitivity is largely reliant on the relationship between the resources, and the community, and the impacts of climate change on these resources. Adaptive capacity is influenced by a lot of factors such as social, economic, and institutional factors. Income diversification makes a household have a higher adaptive capacity than an individual or household that have not diversify.

2.3.1 Empirical findings on vulnerability

According to Kelly *et al.* (2000), vulnerability can be reduced only by adapting. They defined social vulnerability as the capacity of an individual or group of individuals or social group to respond to any negative impacts on their livelihood and wellbeing placing much focus on their economic and institutional constraints. A case study in their research in Vietnam revealed that poverty, inequality to communication and cultural barriers influenced vulnerability levels in the country. IPCC opined that vulnerability to climate change is affected by social, economic and political circumstances affecting how individuals, society and communities cope with its impacts. According to them, vulnerability now encompasses non-climatic factor that poses threat to mankind. Brooks *et al*. (2005), recognized the main indicators of vulnerability and grouped them into three main broad categories. They are health status, governance and education. The health status focused more on the environment that people live in it is more concerned about the sanitation and the calorific intake of people. The maternal mortality is also considered in the health status. The educational status includes literacy rate. The rate at which people can read and write in the society they find themselves. This plays a more important role in people's employability in non- manual jobs. The freedom and capacities of citizens to play a part in the political process was also considered in the governance process. This indicator helps in assessing the vulnerability of society or a population and not an individual.

Gbetibouo *et al.* (2010), conducted a study on the vulnerability of the South African farming sector to climate change and variability. Exposure, sensitivity and adaptive capacity identified as the three main components of vulnerability, according to the IPCC definition were used for the study. They observed that provinces with low adaptive capacity and also high sensitivity do not edge with those exposed to climate change and variability. Vulnerability was also associated with social and economic development. They further found that, the Western Cape and the Gauteng province, which has a high infrastructure development, low illiteracy and a great number of the people not working in the agricultural sector has a lower vulnerability index compared to those in the Limpopo, Eastern Cape and Kwazulu-Natal with overpopulation, large number of its population involved in the agricultural sector mainly rain-fed and large number of farmers being subsistence have a large vulnerability index. They suggested a regional contrary to national policies to solve the susceptibility and variability to climate change in South Africa. In India, O'Brien *et al.* (2004), also assesses the vulnerability to climate change and globalization by mapping multiple stressors. They found that upon the constraints of the study, the study can be used in assessing climate change impacts in the context of change in society. Etwire *et al.* (2013), in their work, assessed the susceptibility of farmers to climate change and variability using the livelihood vulnerability index in Northern Ghana. They found the Northern region to be the most susceptible among the three regions in terms of climate change its fluctuations. They ascribed the vulnerability of the region to the lack of weather information, variations in rainfall and temperature, large household size, high illiteracy and lack of access to proper health care. The Upper West region was sensitive to extreme climate events because of its lack of food and water resources. The most vulnerable region in the Northern Ghana according to their research was Upper East regions in terms of adaptive capacity and this can be attributed to migration out of the region. They recommended the construction of more community health centers across the northern region and more boreholes to decrease the time spent in fetching water. They also recommended government and Non-governmental agencies to increase the priorities to the upper east region interns of projects concerning income generation and enhancement of food security.

But vulnerability measurement has shifted from global (Brooks *et al.* 2005), national and regional (Gbetibouo *et al*. 2010; O'Brien *et al*. 2004) to household (Etwire *et al*. (2013); Boudreau *et al.* 2008; FANRPAN 2011; Skjeflo, 2013) level because social and economic activities occur at the household level.

Deressa (2013), concluded that vulnerability in terms of poverty tends to increase with large family size and high illiteracy level whiles poverty reduces for small size families with education. This implies that institutions play critical a role in reducing vulnerability.

2.4 Perception Theory

The process of identifying (being aware of), unifying (gathering and storing) and interpreting (binding to knowledge) sensory information is known as perception. People form their perception based on their personal experience, knowledge and character (Fessenden-Raden and Heath 1987). Information about the environment is acquired by the sense organs such as eye, ear and nose which are part of the sensory system of an individual to receive information and transmits sensory information to the brain. This sensory information is then used for intuitive judgement about things. Individual formation of intuitive judgement about potential risk hazards is known as one's risk perceptions (Slovic, 1987)

A bigger problem today to the psychologist is the explanation of how physical energy revealed by sense organs form the basis of perceptual experience. Some claim that the observation process is not straight, but subject to the outlooks and prior knowledge as well as the information available in the stimulus itself. Gibson (1966), proposes a theory of direct perception that is a bottom-up approach, while Gregory (1970), also proposes a theory of indirect or constructivist perception that is a top-down approach.

Gregory (1970), said that perception is a productive procedure which depends on top-down processing. He stressed that information or evidence from the environment is usually not clear, to interpret it as logical, we need higher intellectual information either from the previous experience or stored knowledge, to make interpretations of what we perceive.

Gibson (1966), rather argued that perception is direct and not subjected to hypothesis testing as Gregory proposed. The bottom-up theory argues that perception includes an innate procedure that has been forged by evolution and that no learning is required. He opined that there is sufficient evidence in our environment to make meaning of the world in a direct way. His theory is famously known as 'Ecological Theory' because it can only be explained solely in terms of the environment. Human response to environmental issues has been broadly categorized as cognitive, affective, behavioural and physiological (Zube, Sell and Taylor, 1982)

2.5 Perception of Farmers about Climate Change

The way in which farmers deal with climate risk and hazards are all attributed to how they foresee the changes in climate over time. Farmers' perception that climate has changed is the beginning of the process to recognize suitable adaptation strategies and implement essential adaptation responses (Maddison, 2006). In Maddison (2006), research, he outlines that the awareness of farmers about climate change and variability can be analysed using three alternatives. The first is to analyse the agriculturist perception of climate change depending on the experience that respondents have. It is expected that farmers with more experience in farming can differentiate climate change from a mere interannual variations. The second alternative is to analyse awareness of climate change from agriculturist relying on the spatial autocorrelation. This is the validation of an individual's view of responses from a neighbouring farmer. Lastly, the third alternative is to analyse farmers responses to climate change based on meteorological data on climate variables. Maddison stresses that the third alternative is the most important and efficient way of validating agriculturist responses or views about climate variability and change.

According to Le *et al*. (2016), Farmers with substantial knowledge of farming will probably notice a change in the climate. These individuals will adopt an adaptation strategy to modify their farming in a more sustainable way. In their research, the most affected agricultural sector by climate change was those involved in aquaculture. This is because adaptation strategies in aquaculture are mostly costly and only a small number of farmers can afford. These strategies involved the building of dikes and planting of mangrove trees around the fish pond. A research by Deressa *et al*. (2011), also found that majority of farmers perceive an increase in temperature and a reduction in precipitation in the Nile basin of Ethiopia and this led to the implementation of strategies by farmers to reduce the effects of climate change.

According to Acquah (2011), farmers' capacity to perceive that climate has changed is a key prerequisite for their decision to adopt and choice of adaptation strategy. He found that the majority of farmers interviewed perceived an upsurge in temperature and a drop-in rainfall. These have made farmers adopting adaptation measures or technologies to decrease the impacts of climate risk. Farmers' behavioral approach to changes in climate will shape their adaptation and mitigation (Le *et al*., 2016). In designing effective policies to support adaptation, it is better to understand farmers' worries and the means in which they perceived a change in climate (Abid *et al*., 2015). Ndamani & Watanabe (2015), report that farmers' observations about the roots of climate variability in the Northern part of Ghana are frequently focused on human factors (i.e., deforestation and bushfires) and superstition. Mandleni and Anim (2011), report that 86% of the pastoral farmers in Eastern Cape of South Africa are aware that temperature has gone up over the years in the province accompanied by drought.

Maddison (2006), indicate in his research that majority of smallholder farmers believe that rainfall has dropped over the years with temperature increasing. Nhemachena and Hassan (2007), research about farmers' adaptation strategies in South Africa, Zimbabwe and Zambia. They found that majority of farmers perceived a long-term increased in temperature and a reduction in rainfall with the timing of rains changing and the regions becoming drier. Acquah and Onumah (2011), also researched the perception of farmers in the Western region of Ghana about climate change, and reports that greater number of farmers perceived an upsurge in temperature and a reduction in precipitation. The research of Apata *et al.* (2009), in Southwestern Nigeria on food crop producer's perceptions about climate change, indicate that 89% of the respondent perceived a higher temperature, 68% indicated a violent rain, 65% perceived delayed precipitation and early cessation and 72% perceived high evapo-transpiration.

A research by Akponikpe *et al.* (2010), involving samples from Togo, Ghana, Benin, Niger and Burkina Faso show that most of the respondents indicate a reduction in rainfall and upsurge in temperature characterized by uneven rainfall patterns and increased in the number of hot days. Mertz *et al.* (2009), also concluded in their research that farming households had noticed a lessening in the rainfall pattern and a rise in temperature pattern throughout the year, which has resulted in hot periods becoming longer and cold periods becoming shorter. According to Legasse *et al*. (2013), and Niles & Mueller (2016), there was a contradiction between the trend analysis of either temperature or rainfall and farmers' perceptions about changes of these two climate variables. This contradiction was due to farmers perception being based on recall. However, research by Abid *et al*. (2015); Gbetibouo (2009); Alam *et al*. (2017); Elum *et al.* (2017), shows a conformity of farmers perception with the trend analysis of temperature and rainfall.

Doss and Morris (2001), also stated that the views of the local people, their behaviour and thinking in reaction to climate change, as well as their values and aspirations have an important role to play in providing a solution to climate change

2.6 Empirical Findings on Adaptive Capacity

The capacity to strategies and the usage of adaptation strategies or technologies to alter the influence of climate variability on agriculture is known as adaptive capacity. It is an individual or group's capacity to change in response to or in anticipation of stresses in their environment (Smit and Pilifosova, 2001). This concept was introduced in the climate change literature by the IPCC in the third assessment report, to take into account human issues which represent the underlining factors (socio-political, cultural and institution) which can help or prevent human responses to climate change (Smit and Pilifosova, 2001). IPCC defines adaptive capacity as the capacity of systems, organism, or institution to benefit from, to respond to crises, or to alter to potential damages (IPCC, 2007).

However, the IPCC (2014), defined adaptive capacity as the capacity of a system, institutions, humans and other organisms to alter a possible harm or to take the benefit and react to its outcomes. Klein, (2002), also defined adaptive capacity to climate change as the capability of an individual or a system to alter with changes in climate to decrease the prospective damages or impacts and adjust with the outcomes. For an individual to reduce or prevent vulnerability to climate change, must adjust its activities to better suit the current climatic conditions. Adaptive capacities varied from each farmer to farmer depending on factors known to each other (Mabe *et al*., 2012).

According to McCarthy *et al*. (2001), the adaptive capacity of a system is not caused by a single factor as portrayed but rather multiple factors. Adger *et al.* (2007), proposed two dimensions associated with adaptive capacity and they are generic and impact-specific dimensions. The generic dimension aspect of adaptive capacity deals with the capacity of the system, organism, or human being to respond to changes in climate variable while the impact-specific dimension deals with the ability of the system, organism or human being to respond to climate change phenomenon. Schneiderbauer *et al.* (2013), suggested the use of the sector-specific dimension of adaptive capacity, which represents the capacity of an economic sector to adapt to the general impact of climate change.

Jones *et al*. (2010); Adger *et al.* (2007); and Kruse *et al.* (2013), identified factors such as economic development, equity, education, technology, infrastructure, institution, knowledge, and social capital as a generic dimension determinant of adaptive capacity. But Smit and Wandel 2006 also classified factors such as access to finance, technology and information resources, infrastructure, managerial ability, institutional environment within which adaptation takes place, political and kinship networks as a determinant of adaptive capacity as a scale specific and at the local level.

Asante *et al*. (2012), Nakuja *et a*l. (2012), Mabe *et al*. (2012) and Ghosh *et al*. (2015), estimated adaptive capacities of farmers by using five on-farm traits such as knowledge of the strategy, use of the strategy, availability of such strategy to the farmer, accessibility of the strategy to the farmer and consultation the farmer makes concerning the strategy. These attributes were used to assess the adaptive capacity of farmers at the farm level. Defiesta and Rapera (2014), found out in their research that most of the indicators used in adaptive capacity research are physical, financial, natural, human and social capital.

Mabe *et al*. (2012), studied the adaptive capacities of rice farmers in the Northern region of Ghana. The main objective of the research was to measure the adaptive capacities of rice farmers to climate change and its effect on farm output. They found that farmers adaptive capacity was high for some of the technologies or strategies such as the use of fertilizer, planting early maturing varieties. Farmers were moderately adaptive to planting drought-tolerant varieties, mixed cropping, monocropping, construction of fire belt, changing planting date and the use of dugouts wells.

Construction of bunds, planting of trees and crop rotation were the strategies or technologies that the adaptive capacities were low. Rice farmers in the study area were moderately adaptive to changes in weather, which means that farmers in the study area lack all the needed resources to help them adapt effectively and efficiently to changes in climate.

The researcher used the augmented Cobb-Douglas production function to measure the effects of the adaptive capacity of farmers to climate change on the output of rice. It was found that farmers with high adaptive capacity, got 37% of rice more than farmers with moderate and low adaptive capacity. This finding is consistent with Ghosh *et al.* (2015), whose main research objective was to find farmers adaptive capacity to climate change. They concluded that farmers with high adaptive capacity, obtain more rice than those with moderate and low adaptive capacity. Nakuja *et al*. (2012), also found out that farmers with a high adaptive capacity to increase their income from vegetable farming. They analysed factors that affect farmers' adaptive capacity to storage of water (dugout) to irrigate crops during drought and dry season. The higher the adaptive capacity of a farmer to climate change, the less vulnerable the farmers and his household become to the negative impacts of climate change.

2.7 Concepts of Adaptation to Climate Change

UNFCCC defines adaptation as changes in processes or practices and structures to mitigate potential harm or take advantage of opportunities associated with climate change while IPCC (2007), also defines adaptation as any modification in a natural or human system in response to climate stimuli or their effects, which mitigate damage or exploit opportunities. IPCC's definition is widely followed by researchers, but some point out that adaptation may be partially developed in response to climate stimuli (Dovers and Hezri 2010; Biagini *et al.*, 2014). Biagini *et al*. (2014) proposed that what people generally do to avoid and recover from unusual or extreme climate events is what is called adaptation.

Quan and Dyer (2008), also define adaptation as an ordered process through which societies alter to change in climate by altering their operations and natural resource use and other forms of social and economic organisation. Adaptation is into two types and they are autonomous and planned adaptation. Autonomous adaptation or self-adaptation is a farmer's response to changes in rainfall patterns by changing crops or using different harvest and planting dates. Planned adaptation is deliberate policy reforms, opportunities or response strategies, often multisectoral, aimed at modifying the adaptability of the agricultural system or facilitating a specific adjustment. Adaptation is location and context-specific, with no single method to reduce the risks and vulnerabilities of farmers.

Adaptation in agriculture is modifying prevailing agricultural methodologies to reduce the influence of extreme climate incidence, which will push the production frontier outward (Roco *et al.*, 2014). Several studies Deressa *et al.* (2009); Hassan and Nhemachana (2008); Below *et al.* (2010); Adger *et al*. 2003) have analysed types of adaptation strategies implemented worldwide and more importantly in third world countries mostly in Africa. Climate extreme events introduce several uncertainties to the incomes of smallholder farming households that rely mainly on the weather and climate (Al-Hassan and Poulton 2009). These farmers have been changing their agricultural practices to better suit the variation in climate. Several technologies and strategies such as early maturing varieties, conservation agriculture and drought tolerant varieties, are available for smallholder farmers largely developed by the Council for Scientific and Industrial Research (CSIR) and the research institutions of universities in Ghana to enable them better to adapt to the effects of climate change.

The specific crop cultivated by a farmer determines the type of adaptation strategy that he or she chooses (Dixon *et al*., 2001). Dazé (2007), conducted a vulnerability assessment in Ghana for land resources and revealed the following coping strategies or technologies used by farmers decrease the effects of climate change, these are mixed farming, drought-resistant varieties, soil erosion control, tree planting and preservation, planting early or late maturing varieties, fertilizer use, intensification of land use, agricultural diversification, agriculture in marginal lands, cultivation in most valley bottoms, integration of trees in crops, rearing of goats more than sheep as goats are easy to feed compared to sheep's, changing dietary habits and emigration. Nhamo *et al*. (2014), research also revealed that planting early maturing varieties of seeds, usage of chemical fertilizer, early planting, crop diversity, mulching, tillage and water conservation are the strategies adopted by farmers in the Volta Region to combat the effect of climate change.

According to Fosu-Mensah *et al.* (2012), shifting from and changing crop planting dates have been the main coping strategies for smallholder farmers in the Ashanti region. Their research confirms the findings of Dazé (2007), and the adaptive strategies were quite similar.

In this study, adaptation refers to the way rice farmers are either altering their practice or strategies to adjust to climate change. This can either be self-improvised mechanisms by the farmers (spontaneous adaptation) or recommendation backed by research from government and non-governmental organisations (planned adaptation).

2.8 Adoption of Adaptation Strategies

Adoption of agricultural technologies or strategies is the sole means to reduce vulnerability and adverse effects of climate change (Gbetibouo 2008). According to Hassan and Nhemachena, (2008), adoption of agricultural technology is the same as the strategies undertaken to curb the influences of climate change. The ability of a farmer to adapt to climate risk is affected mostly by the awareness of climate change in their communities. Awareness of climate risk has some great tendencies to drive farmers to adjust or improve their local strategies or technologies to help them to adapt (Tol, *et al.*, 1998).

Maddison (2006), opines that adaptation to climate change is in two stages: first being aware that the climate has changed and then determining to whether to adopt particular measure. He concluded that institutional constraints such as education and free extension advice delivery are some of the factors that will quicken and promotes adaptation. Ribot *et al*. (1996) cited in Adger *et al.* (2003), stipulated that some adaptation by an individual is taken in response to threats to personal or extreme events to climate change referred to as (autonomous adaptation) or undertaken by the government on behalf of the society (planned adaptation).

The main adaptation strategies practice by smallholder farmers in Bangladesh are the modification of farm cultural practice and using crop varieties that tolerate the new climate regime (Selvaraju *et al.*, 2006). Di Falco *et al.* (2012), found that changing crop varieties, adoption of soil and water conservation measures and planting trees were the main types of adaptation strategies that farmers are adopting in the Nile river to combat climate change. It was further argued that these are yield related-strategies which account for 95% of all the adaptation strategies with the rest being non-yield related mostly migration and shifting farming practice from crop to animal production.

In sub-Saharan Africa, farmers have switched from cultivating high water requirement crops to a low water requirement crop (drought resistant) due to reduced precipitation experiencing over the years (Yesuf, *et al.* 2008; Deressa, *et al.* 2008; Nhemachena and Hassan 2008). In Ghana, farmers in regions where flooding is persistent and frequent, plant short duration (early maturing varieties) by altering the planting and harvesting time or date to avoid crop growing and harvesting during the peak raining season (Fosu-Mensah *et al.*, 2012 and Acquah and Onumah 2011). In addition, farmers in sub-Saharan Africa have also adopted off-farm income generation activities, also known as off-farm business, planting of trees on farms, mixed cropping, changing planting dates to suit the raining season due to rainfed agriculture being the dominant method of farming and planting of diversified crops (Deressa *et al*., 2008; Acquah and Onumah 2011; Maddison 2006; Gbtibouo 2009; Fosu-Mensah *et al.*, 2012; Kurukulasuriya and Mendelson 2006).

Methods for water conservation such as rainwater harvesting, reuse of wastewater for agriculture and crop irrigation are also some of the adaptation strategies that farmers have used to manage climate change in areas that are drier or have water stress (Deressa *et al*., 2008; Gbetibouo 2009).

According to research by Deressa, *et al.* (2008); Mandleni and Anim (2011); Mertz, *et al.* (2009), livestock and pastoral farmers have also adapted to climate change to safeguard their livelihood and investment. They adopted a measure such as construction or digging of more boreholes, diverting to off-farm activities or businesses and slaughtering or selling the animals during a long period of drought and restocking after the drought.

2.9 Factors that Influence the Number of Adaptation Strategies to Climate Change

Modelling farmers response to agricultural adaptation measures has become important in recognizing major issues that determine the adoption of the various adaptation measures. Farmer's adaptation behaviours, all over the world is influenced by a multifaceted set of socio-economic, demographic, technical, institutional and biophysical factors (Feder *et al.* 1985 cited in Amdu *et al*. 2013)

Maddison (2006), and Nhemachena *et al.* (2014), all concluded that socio-economic factors including gender, educational status of the farmer, farm experience, farm size and institutional factors including access to extension services, access to credit and access to weather forecasting are some of the determinants of adaptation strategies to climate change

Deressa *et al*. (2009), researched into the determinants of choice of adaptation strategies to climate change and found that household size, gender, access to credit, age, farm income, weather forecasting information, farm to farm extension has a positive determinant to adaption to climate change.

A research by Mukarumbwa *et al.* (2017), on finding factors that influence the number of post-harvest practices adopted by smallholder vegetable farmers in Zimbabwe found that institutional factors such as education, access to credit and market information, coupled with socioeconomic factors such as age, gender, household size, group membership and farm characteristics such as farming experience are the major determinants of the number of post-harvest practices adopted by farmers.

Raghu *et al.* (2014), research found that the information from agricultural extension services was positive and significant shows the factors that influence the number of decisions making on the management practices when they researched into factors inducing adoption of farm management practices in three agro-biodiversity hotspots in India.

According to Boansi *et al.* (2017), research in West African Sudan savanna on farmers' adaptation to weather extremes using Poisson count regression model, they found that institutional factors such as access to credit and extension, infrastructural factors such as distance to market were the major determinants of the number of adaptation strategies. Also factors such as family members abroad, the location had a significant effect on the number of strategies used by farmers. Koirala, (2017) used Poisson regression module to find the determinants of number of adaptation strategies used by farmers in Nepal. He found that, family size, access to credit, number of agricultural trainings, association with number of social groups, log of income significantly affects the number of adaptation strategies used by farmers.

A lot of previous studies have adopted the Poisson regression model to explain the factors that influence the adoption of strategies, innovations or technologies by farmers. Ramirex and Shultz, (2002) used the Poisson regression model to explain the adoption of agricultural and natural resource management technologies by small farmers in Central Americans Countries. They found that, having access to credit, having access to labour and belonging to a community organization have a statistically significant impact on adoption of Integrated Pest Management (IPM) practices. However, education, experience in tree planting, land tenure, frequent contact with other farmers and recent adoption of improved technology also have a statistically significant impact on adoption of agroforestry system technologies. Isgin *et al.* (2008) and Pamuk *et al.* (2014) also used Poison regression model to access the adoption of technologies or innovation by farmers.

Tenge *et al.* (2004), argue that female farmers may have a negative effect on the adoption of soil and water adaptation measures or strategies.

However, a study by Nhemachena *et al.* (2014) found that households with a female head are likely to take up adaptation method for climate change because women are more likely to adapt as they are responsible for much of the agricultural work in the developing countries. But other research found male-headed household to take up adaptation strategies

2.10 Conclusions

The literature suggests that farmers' awareness about climate change can best be analysed by validating their perception with a meteorological data on the climate variable in the study area. This is to confirm or deny the views of the farmers since most views are borne out of memory and not through a proper record. This approach, according to Maddison (2006), is the best and therefore this study will employ this approach to validate the perception of rice farmers to climate change in the study area. Measuring adaptive capacity at the farm level is also the best way to assess farmers' adaptive capacity to climate change. This research, however, will employ the methods of Mabe *et al.* (2012), Nakuja *et al.* (2012) and Ghosh *et al.* (2015) to estimate the adaptive capacity of rice farmers in the Adaklu district.

Since adaptation strategies are area specific, the adaptation strategies of rice farmers will be identified by asking farmers what specific strategies they are using to reduce the impacts of climate change and also by using records of similar strategies used in the country or elsewhere through the findings in the literature. Factors influencing the number of adaptation strategies used by rice farmers will be identified by using the Poisson regression model.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology applied in this study; it includes the conceptual and theoretical framework underpinning the study, key concepts, and methods of data collection and analysis. The chapter also describes the geographical features of the study area.

3.2 Conceptual Framework

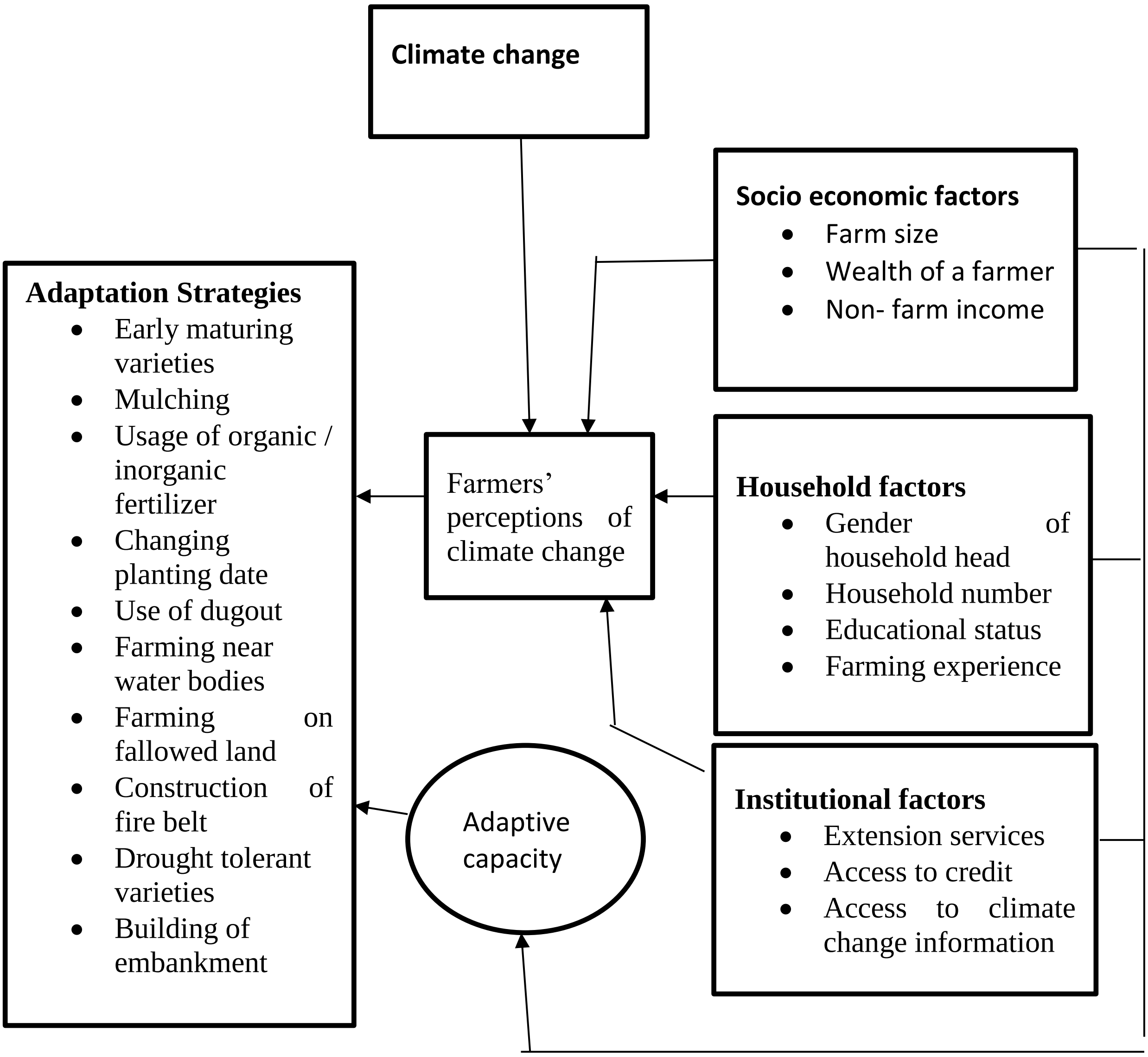
The conceptual framework (Figure 3.1) depicts the linkages between farmers' perception about climate change or variability, the adaptation strategies, the adaptive capacities and the determinants of the number of adaptation strategies that rice farmers choose to use to mitigate climate change. The exposure of the agricultural system to climate change or variability (variable temperature and rainfall) impacts it negatively. Farmers' perception is derived from the negative impacts of weather variables on their farm.

Perception depends on an individual or communal sense of vulnerability and its negative impacts on climate change (Adger, 2003). Rice farmers face climate risk or stresses such as alteration in rainfall, change in temperature, flood, drought and diseases. The lives and livelihoods of rice farmers depend on the rice farm, and any factor that affects the farm also affects the household.

Adaptation to climate change and its related stresses are not in isolation, but technology, socioeconomic, biophysical context that drives this adaptation differs over time, and by location and sector. The adaptive capacity of rice farmers is caused by the complexity of issues such as technology, information, infrastructure, wealth and institutions.

In this study, rice farmers choose different measures or technologies to adapt to climate change depending on their social, institutional, economic and household characteristics.

Farmers' coping mechanisms towards climate impacts are the adaptation strategies they adopt to turn their vulnerability around. The effectiveness of an adaptation strategy determines the output and food security status of the household.



Source: Adapted from Ahmed (2017).

Figure 3.1: Conceptual Framework of Adaptation to Climate Change

3.3 Theoretical Framework

This study is informed by the random utility maximization theory (McFadden, 1973; Cascetta, 2009) and capability theory (Sen, 1999; 2004) and Perception theory (Gregory, 1970)

3.3.1 The Random Utility Maximization Theory

The decision to adopt or not to use any technology or adaptive strategy could be based on expected utility. The expected utility assumes that a smallholder farmer assesses their own production risk and chooses between strategies or technological bundles that are feasible by comparing their expected utility values.

The utility, *U*, that individual *i* gains from the consumption of a good *j*, is made up of an observable deterministic component *V* (the utility function) and a random component Ɛ, and can therefore, be defined as follows:

$$U_{ij} = V_{tJ} + \mathcal{E}_{ij} \qquad (3.1)$$

Cascetta (2009), assumes that the individual utility *U* depends on choices made from bundles of *J* adaptation choices. The individual farmer is expected to have a utility function of the form:

$$U_{ij} = V\left(X_j, Z_i\right) \qquad (3.2)$$

This means a rain-fed rice farmer adopts an adaptation strategy only when the expected utility of using such strategy or technology is significantly greater than the utility derived from not using the strategy subject to some constraints. A rational farmer who wants to increase his output has to select from a bundle of *j* adaptation strategies. A farmer *i* will use among a *j* set of technologies if the alleged benefits from the choice is bigger than the utilities from the other choices Q if $U_j > U_Q$.

Farmer socioeconomic characteristics and the attributes of adaptation itself X_j is assumed to determine the utility derived from any adaptation strategy or technology (Cascetta, 2009). A farmer's choice may not be seen to be what is preferred options, this variation will be explained by the introduction of a stochastic error term as a component of the utility function. Therefore, equation 3.2 can be re-written as:

$$U_{ij} = V(X_j, Z_i) + \varepsilon(X_j, Z_i) \qquad (3.3)$$

The possibility that farmer *i* will select adaptation choice *j* among the bundles of adaptation choices *k* may be expressed as:

$$P\lfloor i|CS\rfloor = P[U_j > U_q], \qquad \forall j \in CS \qquad (3.4)$$

$$= P[(V_j + \mathcal{E}_j) > (V_q + \mathcal{E}_q)]$$

$$= P[(V_j - V_q) > \xi]$$

Where CS is the complete choice set of adaptation strategy or technology option. To estimate equation 3.4 the distribution of the error term must follow the assumption of Gumbel, independently and identically distributed (McFadden, 1973)

3.3.2 Capability theory

The capability theory by Amartya Sen (1999), measures the level of a person's substantive liberty to achieve a functioning life. These functions represent the various things a person is able to do. The basic appeal of capability theory is its emphasis on what a person or persons is/are effectively able to do and to become.

Climate change will affect what an individual or community is capable of doing with the available scarce resources. If climate change affects farming, then farm work will be limited, making climate change a barrier to functioning lives (Schlosberg 2009). The capability-based approach should not be a top-down approach, or expert-driven, but rather an inclusive approach of individual farmers and the community as a whole. The individuals and community should define their own risk and vulnerabilities; this will help in designing adaptation policies and measures that will aid them to mitigate the effects of climate variability.

This method provides a way of analysing the precise needs of an individual or community and identifying the barriers people encounter to adapt to climate change. It also aids in designing and applying adaptation policy towards the preservation of specific abilities under threat from climate change and determining the achievement via adaptation measures or policies.

3.3.3 Perception theory

The perception theory by Gregory Richard Langton (1970), stipulates that an individual makes decisions based on information or evidence gathered from the environment in which they live. This information or evidence is intellectual past experience or stored knowledge on which a farmer takes a decision.

An individual or a farming community will take an adaptation strategy based on knowledge of climate risk experienced on their farms. These adaptation strategies are adopted based on the experience and signals taken from the environment. Farmers experience with the weather over time will inform the choices that they make on their farms. These choices are selected from several strategies available to the farmer. Gregory further explains that information from the environment is received by the sensory organs. To take a meaningful decision, a farmer must combine the information that has been gathered from the environment to what he or she has in memory or record.

How an individual will perceive or react to the climate of an area will largely depend on the experience or a known information of the area.

Farmer's perception of climate change will shape their agronomic practices, and even the type of crops to grow. Their perception of climate which informs their adoption of strategies will also guard their livelihood, income and provide food security for the family and the community.

3.4 Methods of Analysis

3.4.1 Farmers' perception of climate change in the study area

The first specific objective of the study is to assess rice farmers' perceptions of climate change in the study area in relation to temperature and rainfall. Descriptive statistics of perception are compared to a semilog regression model of rainfall and temperature data for 42 years in the district.

The semilog regression model is expressed as

$$\ln A = a + bT \quad (3.5)$$

where;

A= temperature or rainfall, a = intercept, b = slope, T= time in years

3.4.2 Estimating the adaptive capacity of rice farmers

The adaptive capacities of rice farmers are obtained by dividing the total score of the five attributes, namely knowledge, use, availability, accessibility and consultation of farmers on the several strategies, or technologies being practiced. These practices are scored quantitatively depending on the level of the farmer's accomplishment relative to each of the attributes. Effective adaptation means high adaptive capacity, making the likelihood for adaption to be one (1) and zero (0) otherwise. A respondent needs an average score of one (1) to be considered highly adaptive, that is having high adaptive capacity to be considered as fully adapted. Respondents with a score less than 1 are considered as having very high, high and low level of adaptive capacity to climate change. The adaptive capacity (AC) for the i^{th} respondent is obtained by the equation (3.6) on the scale of 0 ≤ AC ≤ 1.

$$AC_{ij} = \frac{K_{iJ} + U_{iJ} + V_{iJ} + A_{iJ} + C_{iJ}}{T} \tag{3.6}$$

where: AC_{ij} represent the i^{th} farmer's Adaptive Capacity to a strategy j, *K*, the knowledge of the farmer has regarding the strategy; *U*, the level of usage of the strategy or technology; *V*, availability of the strategy or technology to the farmer; *A*, accessibility of such strategy or technology to the farmer; *C*, the level of consultation made by the farmer on the strategy and *T* the sum of all attributes *(T=5)*. The degree of each attainment of attributes were categories into four, with 1 and 0.25 being the highest and the lowest score respectively. The farmer with a very high degree attainment gets a score of 0.75 whiles that of high gets a score of 0.50.

Table 3.1: Score level of farmer's achievements of attributes

Level	Scores	Knowledge	Use	Availability	Accessibility	Consultation
Highest	1.00	Very well	Several	Very regular	Very accessible	Several
Very high	0.75	Well	Twice	Regular	Accessible	Twice
High	0.50	Fairy well	Once	Occasional	Not easy accessible	Once
Low	0.25	Not well	Never	Never	Not accessible	Never

Source: Adapted from Nakuja *et al.* (2012), Mabe *et al.* (2012) and Ghosh *et al.* (2015)

The average adaptive capacity of farmers to *j*th adaption strategy, *AveAdapCapj* is calculated using the equation (3.7) below:

$$AveAdapCap\ j = \frac{\sum_i AdapCap_{ij}}{N} \qquad (3.7)$$

Where N is the number of observations of farmers

For the purpose of clearer analysis to inform policies and recommendations on the adaptive capacities of rice farmers in the Adaklu district, the adaptive capacities were categorised as low adaptive capacity (AC_i,< 0.33), average capacity ($0.33 \leq AC_i < 0.66$) and high adaptive capacity ($0.66 \leq AC_i \leq 1.0$).

Table 3.2: Level of adaptive capacities of farmers

Level of Adaptive Capacities	Range of indices of $AdapCap_{ij}$
Low Adaptive Capacities	$0 < AdapCap_{ij} < 0.33$
Moderate Adaptive Capacities	$0.33 \leq AdapCap_{ij} < 0.66$
High Adaptive Capacities	$0.66 \leq AdapCap_{ij} \leq 1.00$

Source: Adapted from Ghosh *et al.* (2015); Nakuja *et al.* (2012), Mabe *et al.* (2012)

3.4.3 Identifying the adaptation strategies used by rice farmers

In identifying the adaptation technologies or strategies rice farmers use to mitigate climate change in the study area, a list of strategies adopted from the local and international literature was presented to farmers through interviews with individual farmers. Rice farmers selected the adaptation strategies that they are adopting on their various rice farms to decrease the impacts of climate change. The choices were analysed with descriptive statistic.

3.4.4 Identifying the determinants of the number of adaptation strategies adopted

The Poisson Regression Model (PCRM) was used to identify the factors that determine the number of coping strategies that rice farmers have used or use to mitigate the effects of climate change on their farms. Adoption of innovations, strategies or technologies by smallholder farmers are not straightforward. Most innovations are like a complementary goods and comes in a pack. They are design in such a way that, it can work together or used individually. Measurements of adoption are often categorically ordered variables, undertaking values such as "none, low, average, high and total". Since the study found that rice farmers are using more than 1 adaptation strategy, then Poisson count regression model was suitable to analyse the determinants of adaptation strategies. The Poisson probability function is given as:

$$f(Y_i|X_i) = P(Y_i = y_i) = \frac{e^{\delta}\delta^{y}}{Y_i} y = 0,1,2,3,4 \qquad (3.8)$$

Where;

Y_i is the number of coping strategies adopted by rice farmers

X_i the explanatory variable made up of institutional, socioeconomic and climate variables.

The dependent variable of the model (y) is the count, ie number of coping strategies adopted by rice farmers in the study area.

The expected mean parameter δ of the probability function is:

$$E[Y_i|X_i] = \delta_i = \exp(X_i\beta) \qquad (3.9)$$

Where;

With all the variables held constant, the incident rate ratio (IRR) for a unit change in Xi is $\exp(X_i\beta)$. Equation (3.9) represents Poisson regression model for count data where the β parameter can be estimated on the basis of equation (3.9) using the maximum likelihood procedure. This procedure is performed by maximizing the log-likelihood function below

$$ln(\beta) = ln\left|\frac{e^{\delta}\delta^{y}}{Y_i}\right| = -\delta + Y_i \ln(\delta) - \ln(Y_i!)$$

$$= \exp(X_i\beta) + Y_i(X_i\beta) - \ln(Y_i!) \qquad (3.10)$$

The Poisson count regression model assumes the mean and the variance of the dependent variable to be same; that is $E(Y_i) = var(Y_i) = \delta$. However, this assumption may not be realistic because the variance of y_i can be smaller causing under-dispersion or larger causing over-dispersion than its expected mean in the count data (Gardner *et al.*, 1995). Standard errors estimate of the Poisson regression parameters will be over-estimated or underestimated thereby giving biased and inconsistent estimates due to unrealistic of the assumption. The count data in most cases have a greater variance than their mean (Gardner *et al.*, 1995). The negative binomial can accommodate the problem of over-dispersion by modelling the variance as a function of the mean (Gardner *et al.*, 1995). The variance function for the negative binomial model (NBM) is specified as

$$var(y_i) = \delta_i + \alpha\delta_i^2 \quad (3.11)$$

where;

α is the dispersion parameter to be estimated?

The negative binomial model will be the same as the Poisson regression if α equal zero. The estimation of the NBM involves the maximization of the log likelihood function expressed below

$$\ln L(\alpha,\beta) = \sum_{i=0}^{n}\{\sum_{j=0}^{yi=0}\ln(j+\alpha^{-1}) - \ln(Y_i!) - (Y_i+\alpha^{-1})\ln[1+ \alpha\exp(X_i\beta)] + Y_i ln\alpha + Y_i(X_i\beta)\} \quad (3.12)$$

If the dispersion parameter α is known and the variance function is correctly specified, then the maximum likelihood estimator for the NBM is robust for distributional errors (Cameron et al., 1988) but, the quasi- generalized pseudo maximum likelihood estimation can be calculated using a consistent estimator if α is unknown (Greene, 2005).

3.5 Survey Design and Data Collection

3.5.1 Sampling techniques and sampling size

A multi-stage sampling technique was employed in choosing rice farmers for this study. First purposive sampling was used to select Volta region because it is now the leading rice producing region in the country and also has more commercial players in the rice industry than any other region in Ghana (MoFA, 2016). The Adaklu district was purposely selected for the study because it is the poorest district in the Volta region (GSS, 2015) and the main agricultural activity is rice farming mainly rain-fed (GSS, 2010).

Secondary simple random sampling was used to select five communities from a list of twenty major rice growing communities in the district for the study. The list of all rice growing communities in the district was obtained from the Ministry of Food and Agriculture district office. Simple random sampling was used to select twenty-five rice farmers only from each community for a sample size of 125.

Table 3.3: Sample Distribution among Communities in Adaklu District Selected for the Study

Communities	Sample size
Kpogadzi	25
Wumenu	25
Sofa	25
Helepke	25
Have	25
	125

Source: Field survey, 2018

3.5.2 Study area

The study was conducted in the Volta region of Ghana. The region has a land area of 20,570 square kilometres and it is the longest region of the country. The Volta Region has a moderate temperature of 21°C-32°C Celsius (70°F-90°F) for most of the year, which characterise a tropical climate (GSS, 2010). Rainfall in the region is bimodal, the first raining season occurs from March to July and the second from mid-August to October (GSS, 2010). The Volta region has all the ecological zones in the country. The region thus has a competitive advantage compared to other regions for the cultivation of many crops. Volta Region population has increased from 2,118,252 in 2010 (GSS, 2010) to 2,549,256 in 2018 with majority of the inhabitants living in the rural areas (GSS, 2017)

The occupations of the people in the Volta region are agriculture and related work consisting of (50.3%); manufacturing (14.1%); wholesale and retail (14.0%); services (3.5%), with professional and technical works accounting for 0.4% (GSS, 2010).

3.5.3 Adaklu District

The vegetation of the district is characterised by short and tall grasses and scattered thickets with few forest and savannah species such as thorny shrubs. The rainfall pattern is bimodal, the major season is from March to June and the minor season is from August to November. The mean annual rainfall of the district is about 1,250mm. The district records its highest rainfall in June; the lowest rainfall is also recorded in December. The amount of rainfall promotes better crop performance in the district. The average monthly temperature is between 24℃ and 30℃ . According GSS, (2010) the district shares boundaries with the Central Tongu district to the south, ,Agortime Ziope to the north and Asuogyaman to the west and Akatsi District to the east (Figure 3.2).

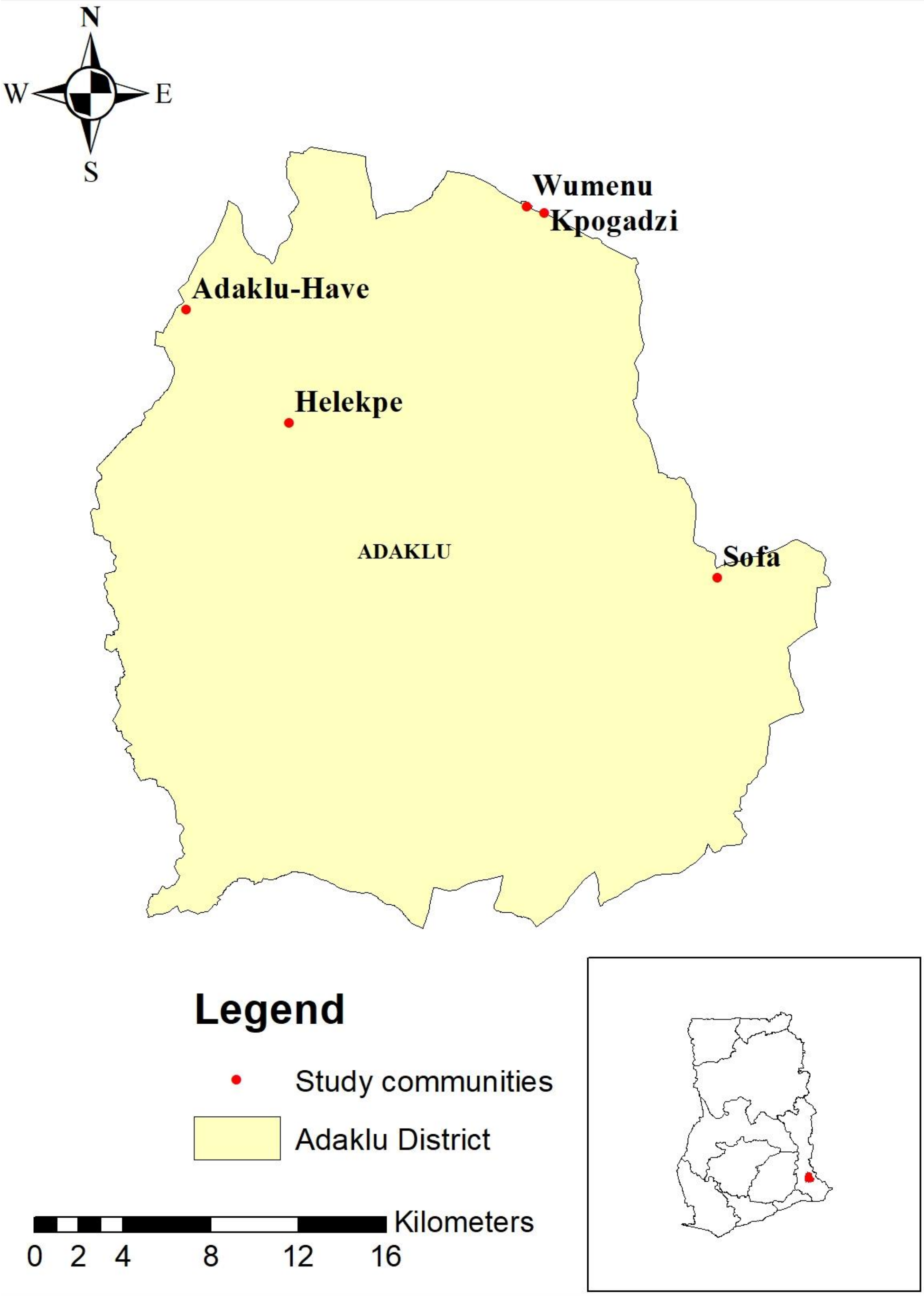


Figure 3.2: Adaklu District Map

3.5.4 Data Collection

The study used both primary and secondary data. The primary data at the farmer level in the districts were solicited using a questionnaire and semi-structured interview. These instruments were used to ensure thorough examination and understanding of the phenomenon. A questionnaire covering variables such as farmer's household demographic characteristics, institutional settings, perception about trends in temperature and rainfall over the years, adaptation strategies among others, was designed, tested and administered at the farmer level.

Secondary data on rainfall and temperature were obtained from the Ghana Meteorological Agency. The reference period for the climate events data was 1976 to 2017. The meteorological rainfall and temperature data were analysed to determine the trend of rainfall and temperature in the district over the past 42 years and to confirm or deny the perception of rice farmers about climate change. Relevant literature from secondary sources was reviewed to support or refute arguments and conclusions about the subject matter drawn. Such secondary sources included journals and the internet. Statistical packages such as STATA 14, SPSS 21 and Microsoft Excel was used in the analysis of the data obtained from the farmer level.

CHAPTER FOUR

RESULTS AND DISCUSSION

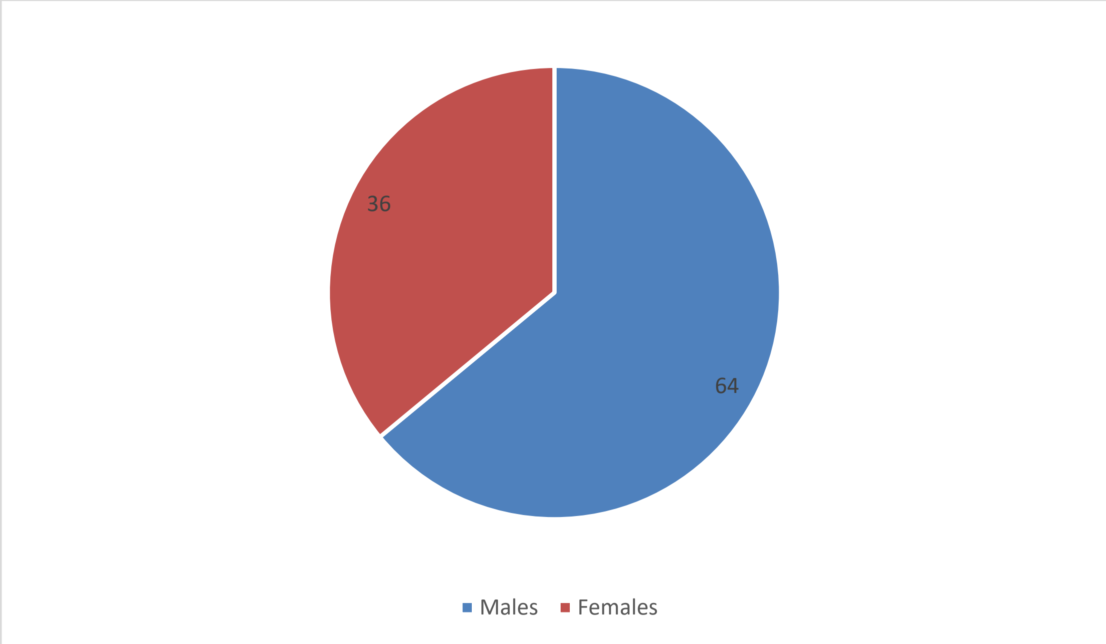
4.1 Introduction

This chapter discusses the study results. The socio-demographic characteristics of the farmers are discussed in section 4.2. Section 4.3 discusses the perceptions of rice farmers about climate change. The results of the adaptive capacity of rice farmers in the study area are also discussed in section 4.4. Following this, the adaptation strategies adopted by the respondents and the determinants of the number of adaptation strategies are discussed in sections 4.5 and 4.6 respectively.

4.2 Socio-demographic Characteristics of Respondents

4.2.1 Gender of respondents

Males are more involved in rice production than females in the study area (Figure 4.1). Focus group discussion with farmers revealed that rice farming is characterized by drudgery, and it is labour intensive and requires physical strength. This confirms the findings of Jenin and Awuni (2001), who reported that 6.7% of beneficiaries of Lowland Rice Development Project were women with most of them having plots for the first time. The gender disparities in rice farming can also be attributed to the fact that most women in the district are engaged in petty trading because of the proximity of any community in the district to Ho, the regional capital which is an advantage for the women to benefit from the biggest market in the region. Most of the farm produce is being sold by women in the market throughout the week



Source: Field Survey, 2018

Figure 4.1: Gender Distribution

4.2.2 Age of respondents

Among the respondents, the adult is engaged in rice farming more than the youth and the aged (Table 4.1). This could be attributed to the drudgery associated with rice farming and unattractiveness of farming to the teaming youth. The results also show that the older farmers are more experienced than the youth. The more experienced a farmer is the more knowledge they have about climatic conditions in the area. The youth constitutes about 22%, while the adults are 75% of the total sample. Thus, the workforce of the study area is high, and this serves as an opportunity for the agricultural sector. The average age of the sample is 43 years with the mean age of males and female respondents being 43 and 41 years respectively.

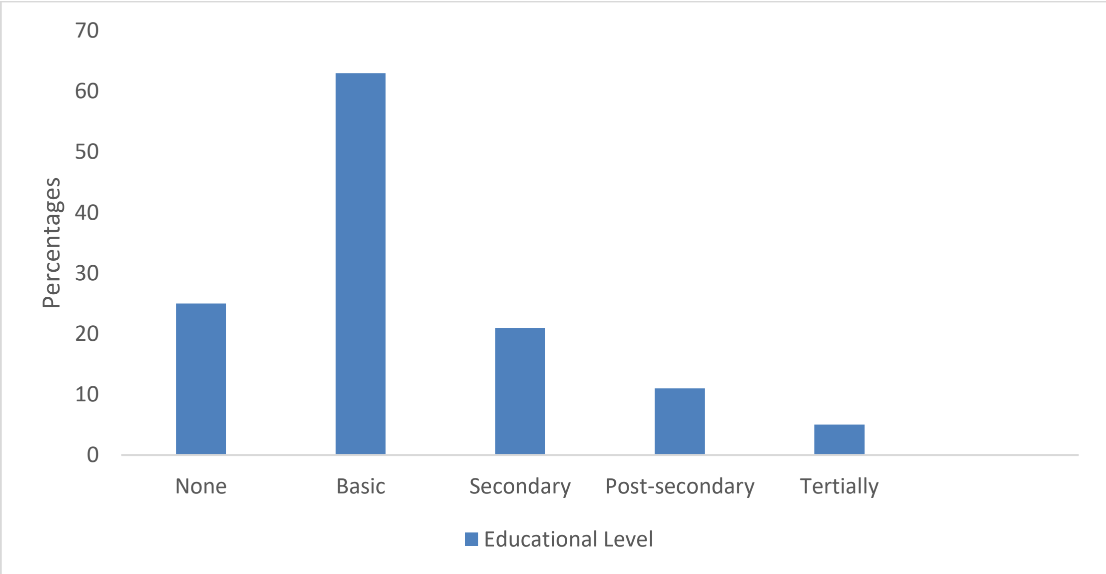
Table 4.1: Age Distribution

Age Group	Frequency	Percentage
<35	28	22.4
35-64	94	75.2
>65	3	2.4
Total	125	100

Source: Field Survey, 2018

4.2.3 Educational status

Education is important for the wellbeing of an individual and the benefit of the society. It helps an individual to make informed decisions that may impact their health and wellbeing. Education provides an individual with the knowledge and skills that lead to better quality of life. It was observed that 19.8% of the respondents interviewed had no formal education. Also, 50%, 16.7%, 8.7% and 4% of the farmers had basic, secondary, post-secondary and tertiary education respectively (Figure 4.2). Tertiary here refers to polytechnics and universities.



Source: Field Survey, 2018

Figure 4.2: Level of Education

4.2.4 Household size of respondents

The household is defined as an individual or a group of individuals, who share the same dwelling unit or compound and share the same household system and forming a single consumption unit (GSS, 2012). The average household size of the sample is 6 (Table 4.2). The average household per house for the districts according to the 2010 PHC is 6, which is higher than the regional average of 4.

Table 4.2: Household size of respondent

Household size	Frequency	Percentage
1	1	0.8
2	6	4.8
3	17	13.6
4	21	16.8
5	20	16.0
6	30	24.0
7	23	18.4
8	4	3.2
9	3	2.4
Total	125	100

Source: Field Survey, 2018

4.2.5 Experience in rice farming

The field survey data analysed revealed that a greater number of the farmers sampled are experienced in rice farming with an average of 9 years. Males are relatively more experienced in rice farming than females in Adaklu district (Table 4.3).

Table 4.3: Mean Years of Farming Experience of Respondents

Sex	Average Years of farming Rice
Males	9
Female	8

Source: Field Survey, 2018

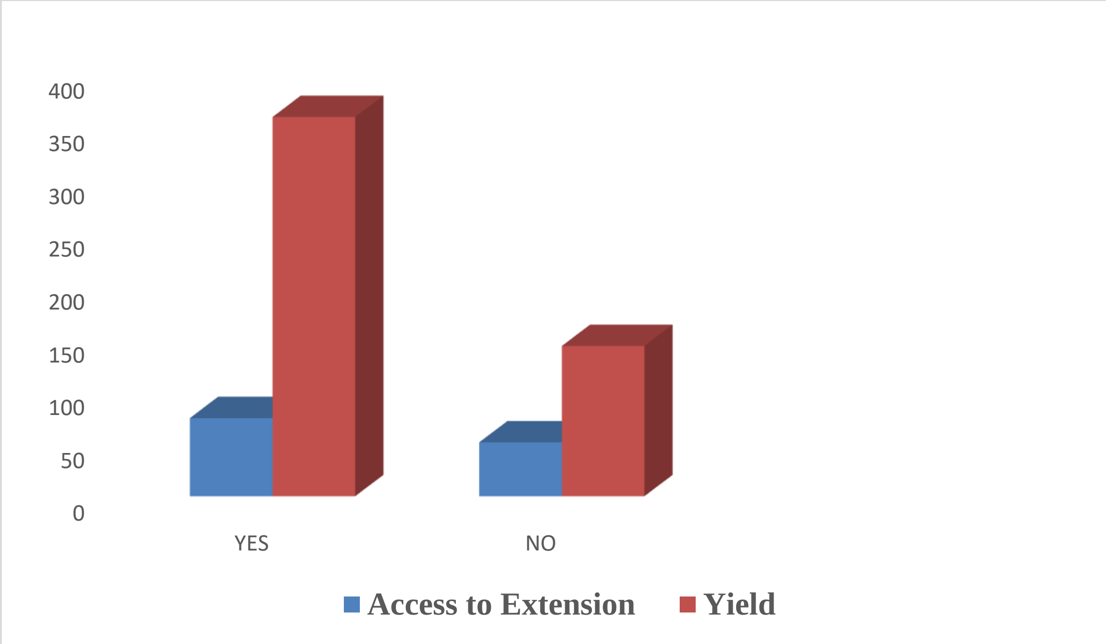
4.2.6 Size of farm holding

The size of the respondent's rice farm ranges from 0.2 to 2.4 hectares with an average of 0.8 hectares. The small size of farm holding could be attributed to inadequate capital to invest in land development and the practice of dividing the land among family members through inheritance and high cost of fairly developed lands in the study area.

4.2.7 Access to extension service

Access to extension services is critical to improving the output of farmers. The output of rice per unit area from respondents' farms has a positive correlation with access to extension. It is believed that extension advice helps to improve farmers agronomic practices on the farm and aids them in making a rational decision on their farm. The yield of rice from respondents who have access to extension was compared to those who do not. Respondents who have access to extension service during the last farming season had higher yields than those who did not get such access. This means that access to extension services or advices not the only factor, contributes to more yield of farmers Respondents with extension access had an average yield of 0.3592 mt/ha compared with 0.142 mt/ha for those without access (Figure 4.3).

Extension service offers an important source of first-hand information on climate change or variability as well as coping strategies. Farmers that have contacts with extension agents are more inclined to use suitable strategies to deal with climate change which will subsequently increase their yield (Hassan and Nhemachena, 2008.).



Source: Field Survey, 2018

Figure 4.3: Access to Extension Service and Rice Yield

4.3 Rice Farmers' Perceptions of Climate Change in the Study Area

In assessing rice farmers' perceptions of climate change in the study area, respondents were asked about their perception of rainfall and temperature for the past 10 years to the time of the survey. Out of the total 125 respondents interviewed, 97.6 % responded they were aware of climate change. Focus group discussions revealed that majority or great number of respondents that said yes to being aware of climate change can be linked to the fact that in the preceding year, the rainfall pattern was bad which affected most farms with many having a total loss of produce. The perception about rainfall and temperature were collated and compared with the trend estimates from the semilog regressions of 42 years meteorological data on rainfall and temperature in the study area.

4.3.1 Perceptions about rainfall

Respondents were asked their perceptions about changes in rainfall for the past 10 years and table 4.4 gives the summary of their responses. From the data analysed, 84% of the respondents perceived a reduction in the amount of rainfall, 12.8% perceived an unpredictable rainfall, 2.4% perceived no change in rainfall and 0.8% perceived an increase in rainfall.

Table 4.4: Respondents Perceptions about Rainfall

Perception	Frequency	Percentage
Unpredictable	16	12.8
No change	3	2.4
Decreased	105	84.0
Increased	1	0.8
Total	125	100

Source: Field Survey, 2018

Fosu-Mensah *et al*. (2012), Acquah (2011), and Ndamani & Watanabe (2015), also report that most of their respondents perceived a lessening in rainfall amount over the years. The responses from the respondents are supported by the findings locally by Acquah (2011), Adjei *et al.* (2011) and Acquah & Onumah (2011), who also report that there is climate change as a result of climate fluctuations in Ghana. Respondents have different perceptions about rainfall amount for the past years.

The results of the semilogarithmic regression of the meteorological rainfall data on the study area for the past 42 years confirms the dominant perception of the respondents in table 4.5. The trend coefficient of the rainfall data is significant and negative showing the decrease in the mean annual rainfall over the years. This confirms the findings of Fosu-Mensah *et al.* (2012), and Acquah & Onumah (2011).

Table 4.5: Estimated Trend of Rainfall in Adaklu District for 42 years (1976-2017)

Variable	Coefficient	Standard Error	P>|t|
Years	-.0013	.0004	0.005
Constant	6.9160	.8843	0.000
Model Diagnostics			
Number of observations	42	R-squared	0.1810
Prob>F	0.0051	Adj R-squared	0.1596

4.3.2 Perceptions about changes in temperature

Majority of respondents perceived an upsurge in temperature while 0.8% perceived no change in temperature and unpredictable temperature (Table 4.6). However, no respondent perceived a reduction in temperature.

The results are consistent with Fosu-Mensah *et al*. (2012) who report that most of the farmers in their study interviewed perceived a rise in temperature.

Table 4.6: Respondents' Perceptions about Temperature

Perception	Frequency	Percentage
Unpredictable	1	0.8
No change	1	0.8
Decreased	0	0
Increased	123	98.4
Total	125	100

Source: Field Survey, 2018

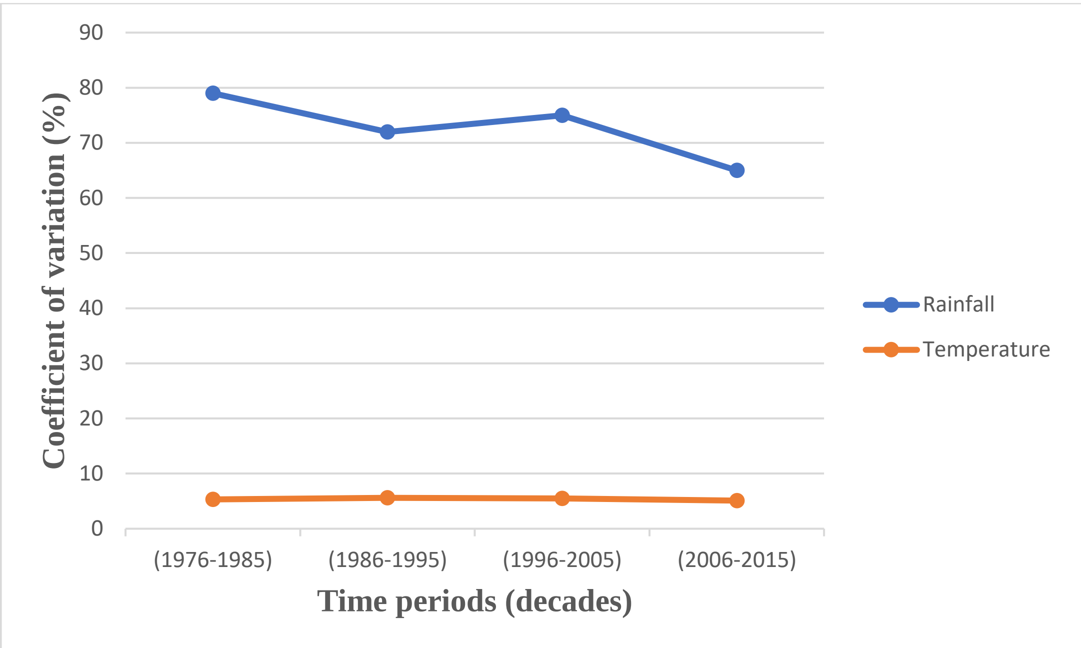
The results of the semilogarithmic regression of the meteorological temperature data of the study area for the past 42 years confirms the dominant perception of the respondents in table 4.7. The trend coefficient of the temperature data is significant and positive showing an increase in the mean annual minimum and maximum temperature in the area over the years. This confirms the findings of Fosu-Mensah *et al.* (2012), and Acquah & Onumah (2011). Who also finds an increase in the mean minimum and maximum temperature in their study.

Table 4.7: Estimated Trend of Temperature in Adaklu District for 42 years (1976-2017)

Variable	Coefficient	Standard Error	P>|t|
Years	0.0007	0.0001	0.0000
Constant	1.9920	0.2801	0.0000
Model Diagnostics			
Number of observations	42	R-squared	0.3589
Prod>F	0.0000	Adj R-squared	0.3429

4.3.3 Variability in climate variables

The graph in (Figure 4.4) describes the coefficient of variation for each of the climate variables. The graph shows the variability of temperature and rainfall over four decades. The variability of rainfall to the mean is high (79%) during the first decade. The last decade recorded the lowest coefficient (65%) in rainfall amount with the second and the third decades recording (72%) and (75%) respectively. Respondents complained about the variability in rainfall pattern over the past 10 years. They further reviewed that, rain falls nowadays are heavy and continuous within some days or even weeks with longer dry spells. The variability in the rainfall data of the study area confirms farmers existing perception about rainfall pattern. The variability in rainfall amount over the past four decades confirms the findings of Owusu *et al.* (2009) who posit that rainfall has been reduced and varying in all ecological zones in Ghana. Temperature over the past four decades has been varying with the last decade recording the lowest (5.1%). The highest temperature to the mean was recorded in the second decade (5.6%), followed by the third (5.5%) with the first decade recording (5.3%). Although respondents complain about excessive heat late in the afternoon and at night, the temperature trend shows a decrease in temperature.



Source: Authors analysis based on GMA data (2018)

Figure 4.4: Variability in Climate Variables

4.4 Adaptive Capacities of Rice Farmers in the Study Area

In estimating the adaptive capacities of the farmers, the respondents were made to respond to five attributes of each adaptation strategy, namely Knowledge of the strategy, the use of it, the availability, accessibility and consultation farmers make on each strategy. The consultation can be a farmer consulting another farmer, an expect or an extension officer about a strategy. This was rated from 0.25 as the lowest to 1 as the highest score. Table 4.8 presents the level of adaptive capacities of rice farmers for various coping strategies. The respondents interviewed had a high capacity to change planting date, use organic or inorganic fertilizer, apply mulching, and planting early maturing varieties. This is because their adaptive capacities calculated are within the range of $0.66 \leq AdapCap_{iJ} \leq 1.00$. Among these adaptation strategies or measures with high adaptive capacities, changing planting date and planting early maturing varieties recorded the highest and the lowest adaptive capacities of 0.91 and 0.71, respectively.

Farmers have moderate adaptive capacities for building of embankment or bunding, farming near water bodies, farming on fallowed land, using dugout for irrigation and planting drought tolerant varieties. Out of the 10 on-farm adaptation strategies used by respondents, farmers have moderate capacity to 5 of them. Among these adaptation strategies which farmers have moderate capacity to use, building of embankment or bonding had the highest adaptive capacity value of 0.52 whiles the use of drought tolerant rice varieties recorded the lowest of 0.40. The calculated capacities to adopt farming near water bodies, farming on fallowed land and the use of dugout are 0.43, 0.41 and 0.40 respectively. The respondents in the study area have a low capacity to construct a fire belt. The construction of fire belt has an adaptive capacity of 0.30. The basis for the classification of adaptation strategies into high, moderate and low is to find out which of the strategy's farmers have a high capacity to use and which one's farmers still need a lot of education or sensitisation programme to improve their use.

Generally, the average adaptive capacity of respondents is 0.51. This implies that farmers in the study area have moderate adaptive capacity to climate change. This confirms research by Mabe *et al*. (2012), and Ghosh *et al*. (2015), who also found respondents to be moderately adapted to climate change.

Table 4.8: Levels of Adaptive Capacities of Farmers

Adaptation Strategies	Adaptive Capacities	Ranks	Level of Adaptive capacities
Changing planting date	0.91	1	High adaptive capacity
Use of chemical or organic fertilizer	0.78	2	High adaptive capacity
Mulching	0.75	3	High adaptive capacity
Planting early maturing varieties	0.71	4	High adaptive capacity
Building of embankment or bunding	0.52	5	Moderate adaptive capacity
Farming near water bodies	0.43	6	Moderate adaptive capacity
Farming on fallowed land	0.41	7	Moderate adaptive capacity
Use of dugout wells	0.40	8	Moderate adaptive capacity
Using drought resistant varieties	0.40	8	Moderate adaptive capacity
Construction of fire belt	0.30	9	Low adaptive capacity
Average	**0.51**		**Moderate adaptive capacity**

Source: Field survey, 2018

4.4.1 Degree of adaptive capacities of respondents

Generally, 7.2% out of 125 farmers interviewed have a high capacity to adapt strategies, while 92.8% of the respondents have moderate adaptive capacities (Table 4.9). No farmers were recorded as having a low adaptive capacity. The mean adaptive capacity calculated is 0.60 which falls within the range of moderate adaptive capacity ($0.33 \leq AveAdapCap_j \leq 0.66$). This implies that on average, farmers in the study area do not have all the necessary resources to aid them to adapt effectively to climate change.

Table 4.9: Mean Adaptive Capacity of Respondents by Level of Adaptation

Adaptive Capacity	Mean Adaptive Capacity	Frequency	Percentage
High adapters	0.69	9	7.2
Moderate adapters	0.51	116	92.8
Low adapters	0.00	0	0.0
Average	0.60	125	100.0

Source: Field survey, 2018

4.5 Identification of Adaptation Strategies used by Rice Farmers in the Study Area

In identifying the adaptation strategies that rice farmers used to mitigate climate change in the study area, respondents were asked to name or describe the adaptation or coping strategies used when rainfall and temperature are not favourable. Rice farming in the district is solely rain fed so all farmers rely on the rainfall before planting. The most dominant strategy adopted is changing planting date (97.6%) and the least adopted strategy is the use of dugout wells (Table 4.10).

Changing planting date: Majority of the farmers (97.6%) interviewed are adopting this strategy due to the nature of the weather in recent years in the study area. The interval between the first four rains is taken into consideration seriously. When the interval between the third and the fourth rain in March is less than two weeks, then farmers start preparing their lands to sow in April. They synchronize their planting within the valleys to minimize the effects of birds. Other farmers synchronize their planting so that rice maturity will meet the flowering of wild grasses. These wild grasses provide feed for the birds, thereby reducing their effects on paddy feeding.

Planting early maturing and Drought resistant varieties: Farming households (73.6%) in the communities surveyed used several adaptation strategies to reduce the risk of climate change. Improved rice varieties such as the Jasmin 85, AGRA Rice, Ex-baika, Gbewaa Rice, and Amankwatia were the most cultivated rice varieties among the farmers (Dogbe *et al.*, 2016). These are lowland rice varieties that have been developed and released by the CSIR- Crop Research Institute (CSIR-CRI) of Ghana production in different ecological zones in the country. These varieties are early maturing compared to the indigenous variety, they taste better and are also perfumed to suit the current market demand for long grain perfumed rice in the country.

Table 4.10: Frequency of Responses for Adaptation Strategy

Adaptation strategies	Percentage of farmers who chose an adaptation strategy (N = 125)	Ranks
Changing planting date	97.6	1
Planting early maturing varieties	73.6	2
Use of chemical or organic fertilizer	68.8	3
Mulching	68.0	4
Non-farm business	67.2	5
Construction of fire belt	51.2	6
Building of embankment or bunding	37.6	7
Farming near water body	36.0	8
Farming on fallowed land	10.4	9
Using drought resistant varieties	4.0	10
Dugout wells	3.20	11

Source: Field Survey, 2018

Application of Organic or Inorganic fertilizer: About 68.8% of farmers interviewed apply organic or inorganic fertilizer. The improved lowland rice varieties released to farmers are highly responsive to inputs such as fertilizer (organic or inorganic) insecticides and fungicides (Fageria *et al.*, 2001). These rice plants require a lot of nutrients both micro and macronutrients to complete its production cycle but needs nitrogen more than any other nutrient to grow vegetatively and to yield more. Urea, Ammonia and NPK fertilizers all have nitrogen as the dominant nutrient component. Farmers' access to fertilizer has been increased due to the government flagship programme "Planting for Food and Jobs" in the district. This has also contributed to most rice farmers applying fertilizer on their fields.

Farming near water bodies: This is not a climate smart adaptation strategy because of the risk of flooding of the field during excessive rainfall but rice field near water bodies are highly sought for in the district. This is because of the potential of using the land for farming during the dry season, mostly for growing vegetables (okra, garden eggs, cabbage and tomatoes) or maize by using the water in the river for irrigation. This is the reason why some 36% of rice farmers are using this as a climate adaptation strategy in the study area.

Mulching: The dead weeds after the application of broad-spectrum herbicides during land preparation are slashed to cover either pre-germinated or dry rice seeds broadcasted on the field. This method serves several purposes of which 68% of the sample population are using it. it protects the rice seeds against birds and other rodents, conserving moisture for the young seedling and protecting the young rice seedlings root for an early establishment. The dry leaves also serve as organic fertilizer when decayed, which improves the fertility of the soil.

Construction of fire belt: This is done by farmers to protect their produce on the farm during harvesting. Bushfires are rampant in the study area, especially during the dry season of which 51% of farmers interviewed practice this strategy. Farmers who cannot afford the service of mini-combine harvester have to harvest their rice fields manually. Manual harvesting is time consuming and mostly during harvesting periods, there is a shortage of farm labour for harvesting. So, construction of fire belt is the only option available to farmers to safeguard their produce on the field.

Building of embankment or bunding: This is done by raising mounds of soil to a height of 20-25 cm above the ground. It is constructed around the farm to conserve water when it rains. The bund is open to release water when there is too much water or when there is flooding in the farm. It is costly to construct and also maintain which contributes to only 37% of the farmers adopting it.

Farming on fallowed land: This is not a popular adaptation strategy among rice farmers but few practices it. These lands are always fertile, and it will take years to deplete nutrient of the soil. However, rice farmers must have no or less tress for easy usage of machines and good yields. Farmers who adopted this strategy are those that can only farm maximum of two acres of land. These farmers are among those who cannot afford the price of fertilizer so will rather resort to a fallowed land for maximum output.

Construction of dugout or wells: Some farmers have constructed dugout wells on their farms. These wells serve as a source of water for irrigation. Only a few farmers (3%) have been able to own one due to the high cost of construction. All these boreholes are mechanized to enable efficient distribution of water.

Non-farm business: Rice farmers within the study area have adopted this strategy to reduce the impacts of climate change on their livelihood. Mostly female farmers are involved in non-farm businesses more than the males in the study area. These women are mostly involved in petty trading, selling farm produce and other consumables in the market at the regional capital. This can be attributed to the proximity of the communities in the study area to the regional capital.

Further discussion with the respondents revealed that the cost associated with the adoption of some of the adaptation strategies is high making their adoption by the average farmer difficult. This accounts for low adoption of strategies such as dugout wells and building of embankments.

4.6 Determinants of Factors Influencing the Number of Adaptation Strategies

Farming households adopt coping strategies to effectively ease the influence of climate change. Rice farmers in the Adaklu district adopt more than one strategy to reduce the impacts of unfavourable climate events (Table 4.11). The reason is that most of the strategies are complementary and the adoption of one goes with or automatically leads to adoption of another to effectively respond to variability. For example, farmers who adopt improved rice varieties also use fertilizer because the improved varieties yield more with fertilizer than without fertilizer.

It was observed that most farmers who adopt only two strategies are those that are still planting the local varieties. The farmers argued that the local varieties are not responsive to fertilizer, so the burden of fertilizer cost is taken away by planting the local variety. Most of the local varieties are brown rice with a few being white. They also explained that sometimes the market of the local variety is good due to the low supply of the variety to the market. The sudden rise in demand of the local varieties of rice, especially the brown rice, was also attributed to the perceived nutritional qualities they have over the white polished rice by some consumers. Most farmers have shifted to planting the new improved rice varieties which have a ready market.

Farmers are adopting improved rice varieties either because they are early maturing or resistant to drought. These improved rice varieties (AGRA Rice, Jasmine 85, Ex-baika, Gbewaa Rice, and Amankwatia) are lowland or irrigated rice varieties and require a lot of water. Farmers adopting three or four adaptation strategies are either constructing bunds around the farm or have their farms located at the very bottom of the valley where all the upstream water settles.

Some of the farmers adopting five and six strategies, farm near water bodies with the sole aim of planting vegetables in the dry season with the use of the water from these rivers for irrigation. These farmers have pumping machines and pipes laid on the farm for irrigation. They also pump the water into the rice field during short dry spells or drought. One of the farmers adopting five strategies has constructed a borehole on his farm. This will supply him and the neighbouring farms with water during the dry season and when there is water stress. The owner of neighbouring farms buys fuel for operating the pumping machines and contribute to the servicing and maintenance of the pumping machines. These boreholes are constructed on lands belonging to the farmers either by inheritance or purchase.

Farmers adopting seven strategies are mostly known among the farmers as rich. These farmers are few and they are among rice farmers who can afford the services of mini combine harvesters from the neighbouring districts. Operators of combine harvester operate on developed or partially developed rice fields free from stumps, trees and logs. Farmers adopting 5,6 and 7 strategies mostly have lands that are partially or fully developed.

Table 4.11: Distribution of Farmers by Number of Strategies adopted

Number of adaptation Strategies adopted	Percentage of farmers adopting adaptation strategies (N = 125)
2	2.4
3	17.6
4	34.4
5	24.8
6	17.6
7	3.4
Total	100

Source: Field Survey, 2018

4.6.1 Preliminary diagnostics of the variables to be used in the econometric analysis

This section presents the econometric results of the study. Preliminary diagnostics for statistical problems of multicollinearity and heteroskedasticity were conducted to the variables for socio-economic and institutional factors. Multicollinearity, a state of very high inter-correlations or inter-associations among the proposed independent variables was tested using variance inflation factor (VIF) for all continuous variables and results presented in Table 4.12. The results confirmed that there was no serious linear relationship among the explanatory continuous variables tested since VIF values were less than 10.

For categorical variables, contingent coefficients were calculated, and results presented in Table 4.13. Similarly, results confirmed that there was no serious linear relationship a mong the categorical explanatory variables because contingent coefficients were less than 0.75 in all cases. By rule of thumb, there was no strong association among all hypothesized explanatory variables. Therefore, all the proposed potential explanatory variables were used in regression analysis.

Table 4.12: Variance inflation factor test results for continuous explanatory variables

Variable	VIF	1/VIF
Farming Experience	2.76	0.362896
Education	2.47	0.404266
Farm size	1.39	0.721631
Income	1.23	0.812560
Age	1.14	0.880885
Mean VIF	1.80	

Table 4.13: Contingency coefficient test results for categorical explanatory variables

	Gender	Access to extension	Access to credit	Awareness of climate change
Gender	1.0000			
Access to Extension	0.2628	1.0000		
Access to credit	0.4583	0.4823	1.0000	
Awareness to climate change	0.4369	0.5292	0.8557	1.0000

To detect heteroskedasticity for all hypothesized explanatory variables, white test was used, and results presented in Table 4.14. Unlike the Breusch-Pagan test which would only detect linear forms of heteroskedasticity, white test was preferably applied as it incorporates both the magnitude as well as the direction of the change for non-linear forms of heteroskedasticity (Williams, 2015).

Table 4.14: Test for heteroskedasticity

Source	Chi^2	df	P
Heteroskedasticity	85.63	48	0.0007
Skewness	16.37	9	0.0596
Kurtosis	3.67	1	0.0553
Total	105.67	58	0.0001
Chi^2(48)= 85.63			
Prob > Chi^2=0.0007			

White's general test is a special case of the Breusch-Pagan test, where the assumption of normally distributed errors has been relaxed. The results indicate presence of heteroskedasticity, because the Prob > chi^2 is significant at 1% and therefore reject the null hypothesis of homoskedasticity and accept the alternate of unrestricted heteroskedasticity. To counter this problem, robust standard errors were reported in the subsequent analyses (Cameron and Trivedi, 2009).

Factors influencing the number of adaptation strategies used by rice farmers were determined in a Poisson regression estimation. The results for Poisson regression model are presented in Table 4.15. A goodness of fit estimated chi^2 after the regression was not statistically significant indicating the data fitted the model well. Further confirmation with Negative Binomial Regression presented in Appendix III produced the likelihood ratio, alpha = 0 not significant indicating that Poisson model is appropriate. A significant alpha=0 could be an indication of a potential over-dispersion problem in which case Negative Binomial Regression would be appropriate.

Table 4.15 shows that factors such as gender, education, farming experience, awareness of climate change, income and access to credit significantly influence the number of adaptations strategies that farmers adopt.

Table 4.15: Results of Poisson regressions of the factors that influence the number of adaptation strategies

Variable	Coefficient	Robust Standard Error	P > |Z|
Age	-0.0005	0.0009	0.5620
Gender	0.2324*	0.1265	0.0660
Education	0.1256***	0.2092	0.0000
Farming Experience	0.0086**	0.0031	0.0050
Awareness of climate change	0.1790***	0.0382	0.0000
Income	9.2100**	4.1000	0.0250
Farm size	-0.0146	0.0203	0.4710
Access to Extension	-0.0016	0.1067	0.8760
Access to credit	0.0959**	0.2913	0.0010
constant	0.9909	0.4513	0.0000
Number of observations	125		
Wald Chi2 (9)	1230.33		
Prob > Chi2	0.0000		
Pseudo R2	0.0726		
Log Pseudolikelihood	-210.62412		
Pearson goodness of fit	3.549095		
Prob > chi2 (115)	1.0000		

***, ** and * are 1%, 5% and 10% critical levels respectively. Since the goodness of fit chi-square is not statistically significant indicates that Poisson Regression Model is a better model

Gender was found to be positive and significant at 5% showing that it is highly associated with determinants of number of adaptation strategies in the study area. The results show that males are more likely to adopt new adaptation strategies than their female counterparts. This can be explained by the dominant culture that permits males to have exclusive rights to make farm decisions regarding both short term and long-term adjustments. Gbegeh & Akubuilo (2012) reported that women are often deprived of property rights because of social barriers in many parts of Africa. Thus, they have fewer capabilities and resources than men so far as land management decisions is concerned. Ndamani & Watanabe (2016) also reported that women are less able to diversify income sources and adapt to climate change because of other domestic responsibilities and less control of financial resources.

Education has positive influence on the number of adaptation strategies adopted by rice farmers in the study area and significant at 1% level. This suggests that farmers with education had better information about adaptation strategies in the study area than those who are less educated. Studies by (Bryan*et al.*, 2013; Deressa *et al.*, 2009; Maddison, 2007) also found a significant positive relationship between education of farmers and adaptation to climate change. It can be concluded that farmers with more years of schooling are more likely to adapt to changes in climate compared to farmers with little or no education. A study by Ramirez *et al.* (2000), using Poisson count regression model to explain the adoption of agricultural and natural resource management technologies by small farmers also found education to be significant determinant of adoption of farm technologies or innovations.

Farming experience is positive and significant at 5%. The more experienced farmers are more likely to adopt more strategies than the less experienced, this could probably be that, these experienced farmers have tried several innovations to mitigate the impact of climate change on their farms and have realised which really works well on their farm, taking the cost and benefit into consideration. Age of the farmer on the other hand, did not seem to be of significance in influencing number of adaptation strategies. These results suggest that it is experience rather than age that matters for adopting strategies to respond to climate change. This finding is supported by Hassan and Nhemachena, (2008), Nhemachena *et al.* (2014), who argue that farming experience increases the probability of uptake of innovations because the farmers have a bundle of experience and knowledge of climate in the area.

Awareness of climate change is significant at 5% and positive. As expected, the study showed a positive relationship between climate change awareness and the number of adaptation strategies adopted by farming households. That is, farmers who have seen a change in climate are more likely to adopt a strategy than those who do not. The reason for this positive relationship is that farming in the district is rain-fed and therefore, decrease in rainfall or increase in temperature is likely to constrain agricultural production and hence the need to adapt to the changing climate. Awareness is founded on access to information. Farmers' awareness of climate change in Adaklu district can be drawn from the presence of two radio extension programmes that run on two radio stations every week. This free radio extension education includes weather, climate information and adaptation strategies. This is supported by the findings of Gbetibouo (2009), who argued that agricultural extension improves the efficacy of making an adoption decision by farmers.

Income by rice farmers was found to be significant at 5 percent and positively influence the number of adaptation strategies adopted by farmers. This probably can be link to the effects of adoption of an innovation on yield or output. A technology may be fully adopted or pave way for the adoption of others if and only if it contributes to output increase. Farmers being rational will compare cost of an innovation and the benefits in output. According to Foster *et al.* (2010), the net gain to the farmer for adopting a technology including all cost of using that technology is a key determinant of the adoption of such technology. High income from farm will motivate and also increase the purchasing power of farmers than low income.

Lastly, access to credit positively influenced the probability of adopting more adaptation strategy. Access to credit is positive and significant at 10 percent. An increase in amount of credit received will significantly leads to adoption of improved innovations which will at long run improve farmers mitigation to climate change and results in yield increase. Credit increases financial resources of farmers, reduces cash constraints and allows farmers to purchase important inputs. A study by Ramirez *et al.* 2000 using Poisson count regression model to explain the adoption of agricultural and natural resource management technologies by small farmers also found access to credit to be significant determinant of adoption of farm technologies or innovations. Apparently, with access to capital, farmers tend to use capital-intensive adaptation strategies as they can pay for labour intensive technologies. Beshir *et al.* (2012) highlighted that if households get enough credit, they can purchase climate smart improved seeds and fertilizers on time. Adekemi *et al*. (2016) argued that credit increases the farmers' economy to purchase improved seed, fertilizer and other CSA inputs.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The summary, conclusions and key findings of the study are presented in this chapter. It also contains policy recommendations based on the findings of the study.

5.2 Summary of the Study

The study analysed the perception of smallholder rice farmers and adaptation strategies to climate change. Climate is seen as an environmental aggregate that consists of factors such as temperature, precipitation, humidity and air. The likelihood of becoming affected by the variability in climate, (irrespective of the contribution of individuals and communities to that variability), is simply known as vulnerability to climate change. Specifically, the study analyses farmers' perception about climate change, estimates of on-farm adaptive capacity of farmers, identifies the adaptation strategies used by farmers and the factors that determine the number of adaptation strategies used by farmers. Farmers' perceptions of climate change were validated with a 42 years meteorological data on rainfall and temperature in the study area. The adaptive capacity of farmers to weather variability was measured using five on-farm attributes and the factors determining the number of adaptation strategies was identified. The study was conducted in Adaklu district in the Volta Region. Data was collected using a structured questionnaire in a sample survey of 125 rice farmers during a face to face interview.

The analysis of rice farmers' perceptions of climate change in the study area reveals that majority of farmers perceived a decrease in rainfall whiles 12.8% also perceived unpredictability of rainfall. Respondents' perceptions about temperature also reveal that majority of them perceive an increase in temperature with just 0.8% of perceiving no change and unpredictability in temperature. These perceptions of respondents were validated with the trend analysis of 42 years of meteorological data on rainfall and temperature. The trend analyses result on the data confirms that rainfall has been declining with temperature rising over time.

The adaptive capacity of farmers was estimated using five on-farm attributes. Rice farmers were found to have high adaptive capacity for four strategies (changing planting date, the use of inorganic or organic fertilizer, mulching and planting early maturing varieties). Respondents have moderate adaptive capacity for five strategies (building of embankment, farming near water bodies, farming on fallowed land, use of dugouts and planting drought resistant varieties). However, respondents have low adaptive capacity for construction of fire belt. Generally, respondents interviewed in the study area have average adaptive capacity to climate change.

Rice farmers apply several adaptation strategies or technology to respond to climate change in the study area. Rice farmers were found adopting more than one strategy at a time. The minimum number of strategies adopted was two and the highest was seven. Eleven adaptation strategies used by rice farmers in the study area were identified. The dominant strategy was changing planting date, followed by planting early maturing varieties and the use of fertilizer. The least adopted strategy was dugout wells because of the high cost associated with owning one is high.

Econometric analysis of factors determining the number of adaptation strategies shows that institutional factors such as educational level, awareness of climate change, access to credit, and socio-economic factors such as gender, farm income and farming experience are the determinants of number of adaptation strategies. The educational level of farmers positively affects the number of adopted strategies. It is believed that farmers with education have access to information on adaptation strategies than those that are not educated. Awareness of climate change also determines the number of adaptation strategies that farmers adopt. Farmers who are aware of changes in climate are adopting more strategies than those who are not aware. Access to credit facilities by farmers is believed to increase the purchasing power of farmers, which enable them to acquire inputs and new innovations to enable them to mitigate the influence of climate change on their farm. Males rice farmers were found to be adapting more adaptation strategies than females rice farmers. This was link to males having access to land holdings than females in the district. Farm income were found to be a determinant of number of adaptation strategies by rice farmers because the more the income from rice farm the less constraints that farmers will have in purchasing innovations or strategies such as inputs, implements to be used on the farm. The more experience a farmer is the more strategies he or she adopts. Farmers who have farm rice for some years now have more knowledge in the weather over the study area than those that have less knowledge. These experience farmers have also tried and tested so many innovations and knows which works and does not work well in the study area. So, it is not about age of the farmers but rather the number of years in rice farming that determines the number of adaptation strategies.

5.3 Conclusions

Rice farmers in Adaklu district are aware of changes in climate and their perceptions of climate change are consistent with the trend analysis of meteorological data of the district, which shows rainfall has been varying and reducing over time with temperature also increasing. This perception of farmers about climate change has made the farmers to adopt several adaptation strategies. Farmers are adopting more than one strategy to lessen the effects of climate change with the average number of adopted strategies being 4.5.

Improved varieties which are mainly early maturing, are mostly grown by farmers in the study area. More importantly, if farmers can have access to varieties that will have the characteristics of maturing early and tolerant to drought, it will help them to effectively adapt to climate change. More research and funding are needed for rice seed development to improve the availability of drought tolerant varieties

Farmers are aware of changes in climate and associated risks. Although they have responded to these risks with a number of strategies, their capacity to adapt is only moderate.

Institutional factors such as education, and awareness of climate change must be improved through proper extension delivery on cultural practices, adaptation strategies, good agricultural practices (GAP), climate smart agriculture and climate smart varieties and systems of rice intensification (SRI). These methodologies lay emphasis on climate change and will help inform smallholder rice farmers about the need to consider climate change when planning their farm.

Commercial banks, micro-finance companies, and rural banks should expand their loan portfolio to cover more farmers and reduce or lessen the process that farmers go through before loans are approved. This will ensure timely application of some technologies on the farm by reducing delays in accessing such technologies. Women should be empowered more within the study area so that they may have an equal right to own lands.

5.4 Recommendations

This study has identified adaptation strategies used by farmers to respond to climate change and shows the importance of farmers' perception about climate risk. Adaptive capacities of farmers have also been estimated. The main recommendation is that policies that seek to promote adoption of on-farm adaptation strategies should focus on measures that will increase farmers' adaptive capacity (introduction of improved varieties, new method of farming, system of rice intensification and etc) alongside the promotion of off-farm adaptation strategies.

Farmers adaptive capacities should be enhanced through extension services to boost their adaptation to climate change, this will decrease their susceptibility to climate change and contribute to sustainable yield.

Declining and increased unpredictability of rainfall are the weather risk that rice farmers in the district faced. The government through the Ministry of Food and Agriculture should finance the development of drought resistant or tolerant varieties; this will ensure an adequate and sustained increase in yields.

Expansion of irrigation facilities in the region and the construction of dams in communities through the government flagship project "One Village One Dam" to provide a constant supply of water, will enable farmers to produce rice all year round. This can raise the financial standings of farmers in the district subject to a single production season in a year under rain-fed farming.

Agricultural extension services should be revamped by resourcing the institution and employing more agents. This will make extension services widely available, accessible, and affordable to farmers in the study area to increase the adoption of strategies that will make them less vulnerable to climate shocks.

Access to improved rice seeds of early maturing and drought tolerant varieties must be enhanced so that most farmers can use to mitigate the effects of climate change

Promotion of informal and non-formal education via information centres and lessons for adult farmers are essential for making farmers in the study communities aware of the problems facing them and their consequences. By this, farmers will and develop self-confidence that would make them ready to act for the development of their communities.

REFERENCES

Abid, M., Scheffran, J., Schneider, U. A. & Ashfaq, M. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics*, *6*(1), 225.

Acquah, H. D. (2011). Farmers perception and adaptation to climate change: A willingness to pay analysis. *Journal of Sustainable Development in Africa*, *13*(5), 150-161.

Acquah, H. D. G. & Onumah, E. E. (2011). Farmers' perception and adaptation to climate change: An estimation of willingness to pay. *Agris on-line Papers in Economics and Informatics*, *3*(4), 31.

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16(3), 268-281.*

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J. & Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. *Climate change*, 717-743.

Adger, W. N., Huq, S., Brown, K., Conway, D. & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in development studies*, *3*(3), 179-195.

Adger, W.N. (2003) 'Social capital, collective action, and adaptation to climate change', *Economic Geography*, Vol. 79, No. 4, pp. 387-404.

Adjei, K. A., Ren, L., Appiah-Adjei, E. K., Kankam-Yeboah, K. & Agyapong, A. A. (2011). Validation of TRMM data in the Black Volta Basin of Ghana. *Journal of Hydrologic Engineering*, *17*(5), 647-654.

AHMED, M. (2017). Rural women's perception and adaptation measures to climate change in Yeki woreda, Sheka zone, Southern Nation, Nationalities and People Regional State, Ethiopia (Msc Thesis Haramaya University).

Akponikpè, P. I., Johnston, P. & Agbossou, E. K. (2010). Farmers' perception of climate change and adaptation strategies in Sub-Saharan West-Africa. In *ICID+ 18 second international conference: climate, sustainability and development in semi-arid regions*.

Alam, G. M. M., Alam, K. & Mushtaq, S. (2017). Climate Change perception and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, *17*, 52-63. https://doi.org/10.1016/j.crm.2017.06.006.

Al-Hassan R., Poulton, C. (2009). "Agriculture and Social Protection in Ghana", FAC Working Paper, No. SP04, January.

Amdu, B., Ayehu, A., & Deressa, A. (2013). Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia. African Technology Policy Studies Network. *ATPS* Working Paper *No .77.*

Angelucci, F., Asante-Pok, A., & Anaadumba, P. (2013). Analysis of incentives and disincentives for rice in Ghana.

Apata, T. G., Samuel, K. D. & Adeola, A. O. (2009). Analysis of climate change perception and adaptation among arable food crop farmers in South Western Nigeria. In *International Association of Agricultural Economists' 2009 Conference, Beijing, China* (pp. 16-22).

Asante, F.A., Boakye, A.A., Egyir, I.S. and Jatoe, J.B.D. (2012), Climate change and farmers' adaptive capacity to strategic innovation: The case of Northern Ghana, International journal of development and Sustainability, Vol 1No. 3, pp. 766-784.

Below, T., Artner, A., Siebert, R. & Sieber, S. (2010). Micro-level practices to adapt to climate change for African small-scale farmers. *A review of Selected Literature. Environ. Prod. Technol. Division*, *953*.

Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S. & McNeeley, S. M. (2014). A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Global Environmental Change*, *25*, 97-108. http://doi.org/10.1016/j.gloencha.2014.01.003.

Boansi, D., Tambo, J. A. and Muller, M. (2017). Analysis of farmers adaptation to weather extremes in West African Sudan Savanna. *Weather and Climate Extremes*. 16, 1-13.

Boudreau, T., Lawrence, M., Holzmann, P., O'Donnell, M., Adams, L., Holt, J. & Duffield, A. (2008). The practitioners' guide to the household economy approach. *London: The Food Economy Group, the Regional Hunger and Vulnerability Programme, Save the Children*.

Brooks, N., Adger, W. N. & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global environmental change*, *15*(2), 151-163.

Cameron, A., Trivedi, P., Milne, F. and Piggot, J. (1988), "A microeconomic model of the demand for health insurance and health care in Australia", Rev. Econ. Stud, Vol. 55, pp. 85–106.

Cameron, C. (2011). Climate change Financing and Aid effectiveness. *Ghana Case Study*.

Cascetta, E. (2009). Transportation Systems Analysis. Springer Science & Business Media. Vol. 29, pp 89-167.

Christiansen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R. K., Kwon, W. T., Laprise, R., Magaña, Rueda, V., Mearns, L., Menéndez, C. G., Räisänen, J., Rinke, A., Sarr, A., & Whetton, P. (2007). Regional climate projections: climate change: the physical science basis. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (eds) Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change, 847-940. Cambridge University Press, Cambridge

Dazé, A. (2007). Climate change and poverty in Ghana. Unpublished report by CARE International Ghana.

De Chavez, Tauli-Corpus (eds.) (2008). Guide to climate change. Retrieved from www.tebtebba.org.

Defiesta, G. D. & Rapera, C. L. (2014). Measuring Adaptive Capacity of Farmers to Climate Change and Variability: Application of a Composite Index to an Agricultural Community in the Philippines. *Journal of Environmental Science and Management*, *17*(2).

Deressa, D. F. (2013). Assessing household's vulnerability to poverty in rural Oromiya-Ethiopia. *Journal of Economics and Sustainable Development*, 4(8), 110-117.

Deressa, T. T., Hassan, R. M. & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(1), 23-31. Doi: 10.1017/S0021859610000687.

Deressa, T. T., Hassan, R. M. Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change*, *19*(2), 248-255. https//doi.org/10.1016/j.gloenvcha.2009.01.002.

Deressa, T., Hassan, R. M., Alemu, T., Yesuf, M. & Ringler, C. (2008). Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. Intl Food Policy Res Inst.

Di Falco, S., Kohlin, G. & Yesuf, M. (2012). Strategies to adapt to climate change and farm productivity in the Nile Basin of Ethiopia. *Climate Change Economics*, *3*(02), 1250009.

Dixon, J. A., Gibbon, D. P., Gulliver, A. & Hall, M. (2001). *Farming systems and poverty: improving farmers' livelihoods in a changing world*. Food & Agriculture Organization.

Dogbe, W., Abebrese, S. O., Owusu, R., Inusah, B. & Danaa, A. (2016). Performance of eleven introduced improved lowland rice varieties in the northern Savanna zones of Ghana. *African Journal of Agricultural Research*, *11*(5), 324-329.

Doss, C. R. & Morris, M. L. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, *25*(1), 27-39.

Dovers, S. R. & Hezri, A. A. (2010). Institutions and policy processes: the means to the ends of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(2), 212-231. http://doi.org/10.1002/wcc.29.

Elum, Z. A., Modise, D. M. & Marr, A. (2017). Farmers' perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management*, *16*, 246-257. https://doi.org/10.1016/j.crm.2016.11.001.

Etwire P. M, Al-Hassan R. M., Kuwornu J. K. M. & Osei-Owusu Y. (2013). Application of the Livelihood Vulnerability Index in Assessing Vulnerability to Climate Change and Variability in Northern Ghana. *Journal on Environmental Earth Science 3(2):157-170*.

Fageria, N. K. & Baligar, V. C. (2001). Lowland rice response to nitrogen fertilization. *Communications in Soil Science and Plant Analysis*, *32*(9-10), 1405-1429.

FANRPAN (Food, Agriculture, and Natural Resources Policy Analysis Network). (2011). The household vulnerability index. http://www.fanrpan.org/projects/ seccap/vulnerability assessment/HVI Pilot Summary 20110829.pd.

Feder, G., Just, R. E. & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change*, *33*(2), 255-298.

Fessenden-Raden, J., Fitchen, J. M. & Heath, J. S. (1987). Providing risk information in communities: Factors influencing what is heard and accepted. *Science, Technology, & Human Values*, *12*(3/4), 94-101.

Fleshman Michael. (2007). Africa Gears Up for Climate change. United Nation Department of Public Information. *Africa Renewal 21*(2).

Fosu-Mensah, B. Y., Vlek, P. L. & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495-505.

Gardner, W., Mulvey, E. P. & Shaw, E. C. (1995). Regression analyses of counts and rates: Poisson, overdispersed Poisson, and negative binomial models. *Psychological bulletin*, *118*(3), 392.

Gbetibouo, G. A. (2008). How can African agriculture adapt to climate change. Insights from Ethiopia and South Africa: understanding farmers' perceptions and adaptations to climate change and variability. The case of the Limpopo Basin, South Africa. *IFPRI Research Brief*, 15-8.

Gbetibouo, G. A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa (Vol. 849). Intl Food Policy Res Inst.

Gbetibouo, G. A., Ringler, C. & Hassan, R. (2010). Vulnerability of the South African farming sector to climate change and variability: An indicator approach. In *Natural Resources Forum* (Vol. 34, No. 3, pp. 175-187). Blackwell Publishing Ltd.

Ghana Agricultural News Digest (2012). Retrieved from: *gssp.ifpri.info/2012/04/03/Ghana-agricultural-news-digest.*

Ghana Statistical Service (2010). Population and Housing Census (PHC), Analytical Report, Volta Region.

Ghana Statistical Service (2012). Population and Housing Census. Summary Report of Final Results. http://www.statsghana.gov.gh/docfiles/2010phc/Census2010_Summary_report_of_final_results.pdf

Ghana Statistical Service (2014). Ghana Statistical Living Standards Survey 6 Poverty Profile. *Journal of Chemical Information and Modelling*, *53*(9), 1689–1699. https://doi.org/10.1017/CBO9781107415324.004.

Ghana Statistical Service (2015). Ghana Poverty Mapping Report. GSS, Accra, Ghana.

Ghana Statistical Service (2017). Projected Population by Region and Sex 2010, 2015-2020. Data Production Unit

Ghosh, B. C., Osmani, M. A. G. & Hossain, M. E. (2015). Perception of and Adaption Capacities to Climate Change Adaption Strategies by the Rice Farmers: A Case of Rajshahi District in Bangladesh. *Journal of Economics and Sustainable Development.6*(2). *136-146*.

Gibson, J. J. (1966). The senses considered as perceptual systems.

Greene, W. (2005), Econometric Analysis, 5th ed, Pearson Education, New York.

Gregory, R. L. (1970). The Intelligent Eye (London: Weidenfeld and Nicolson).

Hassan, R. & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(1), 83-104. https://doi.org/10.1007/s00267-008-9197-0.

Hewitson, B. C. & Crane, R. G. (2006). Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. *International Journal of Climatology*, *26*(10), 1315-1337.

International Food Policy Research Institute (IFPRI) (2009) "Climate Change Impact on Agriculture and Cost of Adaptation". Food Policy Report. Washington D.C.

IPCC. (2001). Climate Change 2001: Synthesis Report. Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*, Cambridge.

IPCC. (2007). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Impacts, Adaptation and Vulnerability Summary for Policymakers. Available at: www.ipcc.ch/ipccreports/ar4-wg2.htm.

IPCC. (2014). Annex II: Glossary. *Climate Change 2014: Synthesis Report. Contribution of Working Group I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 117-130. https://doi.org/10.1017/CBO9781107415324.

ISSER. (2017). The State of the Ghanaian Economy in 2016: Institute of Statistical Social and Economic Research, Legon October (2017), *Isser*, 246.

Jenin L. and Awuni, J. (2001) Lowland rice Development Report: *Monitoring and Evaluation Mission 1 Report*, MoFA, AFD.

Jones, L., Ludi, E. & Levine, S. (2010). Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at the local level, Overseas Development Institute.

Kelly, P. M. & Adger, W. N. (2000). Theory and practice in assessing vulnerability to climate change and Facilitating adaptation. *Climatic change*, *47*(4), 325-352.

Klein, R. J. T. (2002). Climate Change, Adaptive Capacity and Sustainable Development. *OECD Informal Expect meeting on Development and Climate Change- Paris France,* (13-14 March), 1-10.

Koirala, Pankaj. (2017). "Can adaptation practices in response to climate change in agricultural sector be explained by socio-economic variables?"- A case from Nepal

Kolleh, J. B. & Tobodawolo, M. J. (2018). Rice farmers perception of climate change and adaptation strategies in the Ketu North District, Volta Region of Ghana. *African Journal of Agricultural Research*. 13(159, 782-791. Doi: 10.5897/AJAR2017.12904

Kranjac-Berisavljevic, G., Blench, R. M. & Chapman, R. (2003). Rice Production and Livelihoods in Ghana: Multi-Agency Partnerships (MAPs) for Technical Change in West African Agriculture. *ODI. Ghana*.

Kruse, S., Stiffler, M., Baumgartner, D. & Pütz, M. (2013). Vulnerability and adaptation to climate change in the Alpine space: a case study on the adaptive capacity of the tourism sector. *European Climate Vulnerabilities and Adaptation: A Spatial Planning Perspective*, 273-287.

Kurukulasuriya, P., and Mendelson, R. (2006). Crop Selection: Adapating to Climate Chnage in Africa. IFPRI, Environment and Production Technology Division. Washington, DC: International Food Policy Research Institute.

Le, T. T., Nguyen, K. A. T. & Jolly, C. M. (2016). Perception, preparedness and severity of climate change triggered events in Ben Tre Province, Vietnam. *International Journal of Food and Agricultural Economics*, *4*(4), 29.

Liverman, D. M. (1990). Vulnerability to global environmental change. *Understanding global environmental change: The contributions of risk analysis and management*, 27-44.

Mabe, F. N., Bruce, S. D. & Yaw, O. A. (2012). Adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the northern region of Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, *11*(11).

Mabe, F. N., Sarpong, B. D. & Osei-Asare, Y. (2013). The empirical evidence of climate change and its effects on rice production in the northern region of Ghana. *Africa Journal of Agricultural Research*, *8*(49), 6548-6556.

Maddison, D. (2006). The perception and adaptation to climate change in Africa. CEEPA. Discussion paper No.10. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa, University of Pretoria.

Mandleni, B. & Anim, F. D. K. (2011). Perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape Province of South Africa. *Journal of Human Ecology*, *34*(2), 107-112.

Mariano, M. J., Villano, R. & Fleming, E. (2012). Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems*, *110*, 41-53.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J. & White, K. S. (Eds.). (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press.

McFadden, D. (1973). *Conditional logit analysis of qualitative choice behaviour*. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, London, U.K., pp. 105- 142.

Mertz, O., Mbow, C., Reenberg, A. & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental management*, *43*(5), 804-816.

Ministry of Environment, Science and Technology (MEST) (2012). *Ghana National Climate Change Policy*. Ministry of Environment, Science and Technology: Accra, Ghana.

Ministry of Environment, Science, Technology and Innovation, (MESTI) (2016). *National Climate Change and Green Economy learning Strategy.*

Ministry of Food and Agriculture, (2011a). Rice Sector Support Project (RSSP). Available from www.mofa.gov.gh/site/?page_id=736.

Ministry of Food and Agriculture, MoFA (2009) National Rice Development Strategy (NRDS) Draft. Kumasi Ghana.

Ministry of Food and Agriculture, MoFA (2011b). Annual Report. *Policy Planning Monitoring and Evaluation Directorate.* Accra, Ghana. P. 103.

Ministry of Food and Agriculture, MoFA (2016). Agriculture in Ghana: *Facts and Figures* Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Accra, Ghana.

Molua, E. L. (2002). ―Climate variability, vulnerability and effectiveness of farm-level adaptation options: The challenges and implications for food security in Southwestern Cameroon, *Journal of Environment and Development Economics*, Vol.7, pp.529-545.

Mukarumbwa, P., Mushunje, A., Taruvinga, A., Akinyemi, B.and Ngarava, S. (2017). "Factors influencing number of post -harvest practices adopted by smallholder vegetable farmers in Mashonaland East Province of Zimbabwe" *International Journal of Development and Sustainability* 6(11), 1774-1790.

Nakuja, T., Sarpong, D. B., Kuwornu, J. K, & Felix, A. A. (2012). Water storage for dry season vegetable farming as an adaptation to climate change in the upper east region of Ghana. *African Journal of Agricultural Research*, *7*(2), 298-306.

Ndamani, F. & Watanabe, T. (2015). Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. *Water*, *7*(9), 4593-4604.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. G., Kaltenborn, B. P. (Eds). (2009). *The environmental food crisis – The environment's role in averting future food crises***.** A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no.

Nhamo, N., Donald, M. & Fritz, O. T. (2014). Adaptation strategies to climate extremes among smallholder farmers: A case of cropping practices in the Volta Region of Ghana. *British Journal of Applied Science & Technology*, *4*(1), 198.

Nhemachena, C. & Hassan, R. (2007). Micro-level analysis of farmers adaption to climate change in Southern Africa. *International Food Policy Research Institute.*

Nhemachena, C., Hassan, R., & Chakwizira, J. (2014). Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics*, *6*(5), 232-241.

Niles, M. T. & Mueller, N. D. (2016). Farmer perceptions of climate change: Associations with observed temperature and precipitation trends, irrigation, and climate beliefs. *Global Environmental Change*, *39*, 133-142.

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H. & West, J. (2004). Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global environmental change*, *14*(4), 303-313.

Organisation for Economic Cooperation and Development [OECD] (2011). OECD Observer. Retrieved on March 3, 2018

Osei-Asare, Y. B. (2010). Mapping of poverty reduction strategy papers (PRSPs), Sector strategies and policies related to rice development in Ghana. Coalition for African Rice Development (CARD) c/o AGRA, Nairobi, Kenya.

Owusu, K. & Waylen, P. (2009). Trends in spatio-temporal variability in annual rainfall in Ghana (1951-2000). *Weather*, *64*(5), 115-120.

Owusu, K., Waylen, P. & Qiu, Y. (2008). Changing rainfall inputs in the Volta basin: Implications for water sharing in Ghana. *Geo Journal*, *71*(4), 201-210.

Pamuk, H., Bulte, E., & Adekunle, A. A. (2014). Do decentralized innovation systems promote agricultural technology adoption? Experimental evidence from Africa. *Food Policy*, 44, 227-236.

Isgin, T., Bilgic, A., Forster, D. L., & Batte, M. T. (2008). Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. *Computers and electronics in agriculture*, 62(2), 231-242.

Adekemi, O. A. Taiwo, T. A. & Akinlade, R. J. (2016). Causal effect of credit and technology adoption on farm output and income: The case of cassava farmers in Southwest Nigeria. *Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists*, September 23-26, 2016, Addis Ababa, Ethiopia

Amikuzuno, J. (2011). Implications of Climate Variability for Yields of Major Staple Food Crops in Northern Ghana: Some Empirical Evidence. In *2011 Conference: Impacts of Climate Change on Agriculture, December 6-7, 2011, Rabat, Morocco*(No. 188552). Moroccan Association of Agricultural Economics (AMAEco).

Beshir, H., Emana B., Kassa B. & Haji J. (2012). Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach. *Journal of Research in Economics and International Finance (JREIF)*, 12:39-49.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of environmental management*, *114*, 26-35.

Cameron, A. C. and Trivedi, P. K. (2009). *Microeconometrics Using Stata*. College Station, TX: Stata Press.

Gbegeh, B. D. & Akubuilo, C. J. (2012). Socioeconomic determinants of adoption of yam minisett by farmers in Rivers state, Nigeria. *Wudpecker Journal of Agricultural Research*. 2(1): 033-038

Maddison, D. (2007). *The perception of and adaptation to climate change in Africa*. The World Bank.

Pettengell, C. (2010). Climate Change Adaptation: Enabling people living in poverty to adapt. *Oxfam Policy and Practice: Climate Change and Resilience*, *6*(2), 1-48.

Quan, J. & Dyer, N. (2008). Climate change and land tenure. The implications of climate change for land tenure and land policy.

Raghu, P. T., Manaloor, V. and Nambi, A. V. (2014). Factors influencing adoption of farm management practices in three agrobiodiversity hotspots in India: an analysis using the count data model. *Journal of Natural Resource and development* 4, 46-53.

Railly, J. M, Graham, J. and Hrubovcat, J. (2000). Agriculture: The Potential Consequences of Climate Variability and Change for the United States. Cambridge University Press, New York.

Ramirez, O. A., & Shultz, S. D. (2000). Poisson count models to explain the adoption of agricultural and natural resource management technologies by small farmers in Central American countries. *Journal of Agricultural and Applied Economics*, 32(01), 21-33.

Ribot, J.C., Magalhães, A.R. and Panagides, S.S., editors, (1996). Climate variability, climate change and social vulnerability in the semi-arid Tropics. Cambridge: Cambridge University Press.

Roco, L., Engler, A., Bravo-Ureta, B. & Jara-Rojas, R. (2014). Farm level adaptation decisions to face climatic change and variability: Evidence from Central Chile. *Environmental Science & Policy*, *44*, 86-96.

Rynikiewicz, C. & Chetaille, A. (2006). Poverty reduction, climate change mitigation and adaptation: the need for intermediate public policies harnessing technology appropriation. In *The future of science, technology and innovation: 40th anniversary conference, SPRU, 11-13 September 2006*.

Schipper, L. & Pelling, M. (2006). Disaster risk, climate change and international development: scope for, and challenges to, integration. *Disasters*, *30*(1), 19-38.

Schlosberg, D. (2009). Climate Justice, the Capabilities Approach, and Potential Policy Implications. In *Prepared for presentation at the final seminar in the series on the EU, Climate Change, and Global Environmental Governance, University of Edinburgh*.

Schneiderbauer, S., Pedoth, L., Zhang, D. & Zebisch, M. (2013). Assessing adaptive capacity within regional climate change vulnerability studies—an Alpine example. *Natural hazards*, *67*(3), 1059-1073.

Scholze, M., Knorr, W., Arnell, N. W. & Prentice, I. C. (2006). A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences*, *103*(35), 13116–13120. https://doi.org/10.1073/pnas.0601816103.

Selvaraju, R., Subbiah, A. R., Baas, S. & Juergens, I. (2006). Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh. Developing institutions and options. *Institutions for Rural Development (FAO)*.

Sen, A. (1999): *Development as Freedom*. Oxford: Oxford University Press.

Sen, A. (2004): Elements of a Theory of Human Rights. In: Philosophy & Public Affairs, Vol.32. Pp. 315-356.

Skjeflo, S. (2013). Measuring household vulnerability to climate change—Why markets matter. *Global environmental change*, *23*(6), 1694-1701.

Slovic, P. (1987). Perception of risk. *Science*, *236*(4799), 280-285.

Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change*, *16*(3), 282-292.

Smit, B., Burton, I., Klein, R. J. & Wandel, J. (2000). An anatomy of adaptation to climate change and variability. *In Societal Adaptation to Climate Variability and Change* (pp. 223-251). Springer, Dordrecht.

Smit, B., Pilifosova, O. (2001). Adaptation to Climate Change in the Context of Sustainable Development and Equity. Chapter 18 in Climate Change 2001:

Impacts, Vulnerability, and Adaptation. Contribution of working group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, *Cambridge University Press. UK, Cambridge*, 877-912.

Stephens, C. S. (1991). Some empirical evidence of global warming in Ghana. *Ghana Journal of Science,31-36, 119-129.* Retrieved from https://inis.iaea.org/search/search.aspx?orig_=RN:29060571.

Sutter, J. D. & Berlinger, J. (2015). Final draft of climate deal formally accepted in Paris. *CNN. Cable News Network*.

Tenge, A. J., De Graaff, J. & Hella, J. P. (2004). Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. *Land Degradation & Development*, *15*(2), 99-114.

Thornton, P. K., Ericksen, P. J., Herrero, M. & Challinor, A. J. (2014). Climate variability and vulnerability climate change: A review. *Global Change Biology*, 20(11), 3313-3328. https://doi.org/10.1111/gcb.12581.

Timmermann, P. (1981). Vulnerability, resilience and the collapse of society. *Environmental Monograph*, *1*, 1-42.

Tol, R. S., Fankhauser, S. & Smith, J. B. (1998). The scope for adaptation to climate change: what can we learn from the impact literature. *Global Environmental Change*, *8*(2), 109-123.

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L. & Polsky, C. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the national academy of sciences*, *100*(14), 8074-8079.

UNFCC. (1992). United Nation Framework Convention on Climate Change. Impacts. Review of European Community and International Environmental Law, 1(3), 270-277. https://doi.org/10.1111/j.1467-9388.tb00046.x.

UNFCC. (2007). United Nation Framework Convention on Climate Change. Impacts, Vulnerability and Adaptation in Developing Countries. UNFCC. 2009. Least Developed Countries Under the UNFCC.

UNFCC. (2015). Conference of the Parties (COP). (2015). Climate Change Conference. Adoption of the Paris Agreement. COP 21. https://doi.org/FCCC/CP/2015/L.9/Rev.1.

United Nation Treaty Collection (2018). Paris Agreement. Accessed on 24 July 2018. https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

United Nations (2007). Ghana. Situation report on floods, UN country team in Ghana. Retrieved on March 28, 2018 from www.reliefweb.int/rw/rwb.nsf/db900sid/EGUA-79RSAK

USDA, (2017) Foreign Agricultural Service, Office of Global Analysis www.apps.fas.usda.gov/psdonline/circulars/grain-rice.pdf.

Williams, R. (2015). Heteroskedasticity. University of Notre Dame, http://www3.nd.edu/~rwilliam

World Bank, (2010). Economic of Adaptation to Climate Change: *Social Synthesis Report, 1818* H Street NW Washington DC, USA.

Yesuf M., Di Falco. S., Deressa, T., Ringler. C. & Kohlin. G. (2008). *The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia, EDRI.* IFPRI Discussion Paper No. 828 Washington, DC: International Food Policy Research Institute.

Zube, E. H., Sell, J. L. & Taylor, J. G. (1982). Landscape perception: research, application and theory. *Landscape planning*, *9*(1), 1-33.

APPENDICES

SURVEY QUESTIONNAIRE
UNIVERSITY OF GHANA
DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
PERCEPTIONS AND ADAPTATION STRATEGIES OF RICE FARMERS TO CLIMATE CHANGE IN THE VOLTA REGION

QUESTIONNAIRE FOR THE STUDY

Questionnaire ID:	Date:
Name of enumerator:	Phone Number:
District:	District code:
Community:	Community code:

A. Demographic Information

1. Name of Respondent: …………………………………..
2. Gender: [………] 1=Male 0=Female
3. Age of Respondent: [……………………]
4. Highest level of formal education of the respondent: […………..] 0=None 1=Basic (Primary/JHS/Middle) 2=Secondary (Secondary/Vocational), 3 = Posts-secondary (Training college/Diploma program) 4 = Tertiary (Polytechnic / University)
5. Marital status of respondents [………..]

0=Single 1=Married 2=Divorced/Separated 3=Widowed

6. Is rice farming your main occupation? [………..] 1= yes 2= No
7. If NO what other work do you do apart from rice farming

a …………………………. ………………… b.………………………………..

8. Number of years in rice farming ………………………………….
7. How many persons are in this household? ………………………..
8. Number of persons with age below 15 years: ……………………..
9. Number of persons between ages 15 and 65 years. …………………..
10. Number of persons with age above 65 years: …………………………
11. What is your current farm size (acres)? [……………..]
12. Do you have access to improved rice varieties (early maturing or drought resistance)? […………] 1= Yes 0 =No
13. Do you have access to farm inputs? [……………] 1=Yes 0=No
14. Do you have access to credit? […………] 1=Yes 0=No
15. Do you have access to extension services? […………..] 1=Yes 0=No
16. Are you a member of an FBO? [……………….] 1=Yes 0=No

B. Perception of farmer on Climate change

17. Have you noticed any changes in the weather condition over the past 30 years? [………] 1=Yes 0=No
18 If yes, what notable changes have been observed
1= Unpredictable 2= Prolonged drought 3= Very hot seasons
4= Very wet seasons 5 Others specify

19 What changes have you observed in the rainfall pattern? [ ]
1=Unpredictable 2=No change 3=Decreased
4=Increased

20 What changes have you observed in the temperature pattern?
1=Unpredictable 2=No change 3=Decreased
4=Increased

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

C. <u>Adaptation/Copping Strategies to climate change</u>

22 What adaptation or coping strategy do you adapt on your rice farm in managing the effects of climate change

Climatic Factors	Adaptation/Coping Strategies
1. Rainfall	
a. Amount per season	
• Decreased in rainfall amount	………………………………………… ………………………………………………
• Increased in rainfall amount	……………………………………………… ……………………………………………
b. Duration per season	……………………………………………… …………………………………………… ……………………………………………
• Short duration	
• Long duration	
c. Period of rainfall	
• Early in the year	
• Middle of the year	
• Late in the year	
2. Temperature	
a Rising temperature	……………………………………………… ……………………………………
b.Decreasing temperature	…………………………………………… ……………………………………………

23. Tick any other adaptation technologies or strategies that you adopt in coping with climate change

S/N	Adaptation Strategies	Very Effective	Effective	Less Effective	Not effective
1	Use of drought tolerant rice varieties				
2	Using formal irrigation				
3	Use of dugout well for irrigation				
4	Changing planting date				
5	Planting early maturing rice varieties				
6	Mulching				
7	Building of embankment				
8	Use of Chemical or organic fertilizer				
9	Construction of fire belt				
10	Non-farm income				
11	Integration of trees in farms				
12	Others				

D. Adaptive capacity of farmers to climate change

24. Fill in the table below by the score for the degree of attainment of each attribute for each adaptation technology/coping strategy to climate change.

Degree	Knowledge	Use	Availability	Accessibility	Consultation
Highest degree	Very well 1.0	Several 1.0	Very regular 1.0	Easily accessible 1.0	Several 1.0
Higher degree	Well 0.75	Twice 0.75	Regular 0.75	Accessible 0.75	Twice 0.75

High degree	Fairly well 0.50	Once 0.50	Occasionally 0.50	Not easily accessible 0.50	Once 0.50
Low degree	Not well 0.25	Never 0.25	Never 0.25	Not accessible 0.25	Never 0.25
Adaptation Technologies					
Formal irrigation					
Dugout					
Early maturing rice varieties					
Drouth tolerant rice varieties					
Changing planting date					
Use of mulch					
Construction of fire belt					
Farming on fallowed land					
Integration of trees in rice farms					
Mixed farming					
Monocropping					

Crop rotation					
Use of chemical and organic fertilizer					
Building of embankment					
Farming near water bodies					

APPENDIX II

Results of Poisson Count Regression

Poisson regression

Number of Observation	=	125
Wald chi2 (9)	=	1230.33
Prob > chi2	=	0.0000
Pseudo R2	=	0.0726

Log likelihood = -210.62412

Add	Coef.	Robust Std. Err.	z	P>z	[95% Conf.	Interval]
Age	-.0005207	.0008987	-0.58	0.562	.0022821	.0012407
Gender	.0232471	.0126572	1.84	0.066	.0015606	.0480548
Education	.1255666	.0209242	6.00	0.000	.0845559	.1665773
Farming Experience	.0086144	.0030551	2.84	0.005	.0026266	.0146023
Awareness of Climate Change	.179052	.0381868	4.69	0.000	.1042072	.2538968
Farm Size	-.0145846	0.0202474	-0.72	0.741	-.0542687	.0250996
Access to credit	.0959115	.0291265	3.29	0.001	.0388247	.1529983
Farm Income	9.21e-07	4.10e-07	2.25	0.025	1.18e-07	1.72e-06
Access to Extension	-.0016616	.0106749	-0.16	0.876	-.022584	.0192608
_cons	.9909956	.0451274	21.96	0.000	.9025476	1.079444

APPENDIX III

Results of Negative Binomial Regression

Negative binomial regression	Number of Observation = 125
	Wald chi2 (9) = 1230.33
Dispersion = mean	Prob > chi2 = 0.0000
Log likelihood = -210.62412	Pseudo R2 = 0.0726

Add	Coef.	Robust Std. Err.	z	P>z	[95% Conf.	Interval]
Age	-.0005207	.0008987	-0.58	0.562	-.0022821	.0012407
Gender	.0232471	.0126572	1.84	0.066	-.0015606	.0480548
Education	.1255666	.0209242	6.00	0.000	.0845559	.1665773
Farming Experience	.0086144	.0030551	2.84	0.005	.0026266	.0146023
Awareness of Climate Change	.179052	.0381868	4.69	0.000	.1042072	.2538968
Farm Size	-.0145846	0.0202474	-0.72	0.741	-.0542687	.0250996
Access to credit	.0959115	.0291265	3.29	0.001	.0388247	.1529983
Farm Income	9.21e-07	4.10e-07	2.25	0.025	1.18e-07	1.72e-06
Access to Extension	-.0016616	.0106749	-0.16	0.876	-.022584	.0192608
_cons	.9909956	.0451274	21.96	0.000	.9025476	1.079444
/lnalpha	- 93.87445					
alpha	1.70e- 41					

Likelihood-ratio test of alpha=0: chibar2(01) = 0.00 Prob>=chibar2 = 1.000