EFFECTS OF CLIMATE VARIABILITY ON TOMATO CROP PRODUCTION IN THE OFFINSO NORTH DISTRICT OF ASHANTI REGION

By

Lawrence Guodaar

B. Ed (Social Studies)

A Thesis Submitted to the School Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi in Partial Fulfillment of the Requirement for the Award of A Degree

Of

MASTER OF PHILOSOPHY

In Geography and Rural Development

College of Humanities and Social Sciences

NOVEMBER, 2015

DECLARATION

I hereby declare that this M.Phil. thesis is the result of my original research. Except for the references cited which have been duly acknowledged, and that no part of it has been presented for another degree in this University or elsewhere. I therefore take full responsibility for the content of this research.

Signature   Date

…………………………………   ………………………………

Lawrence Guodaar (PG9417413)
(Student)

Certified by:

……………………………………   ………………………………

Mr. Felix Asante
(Supervisor)

……………………………………   ………………………………

Dr. Gabriel Eshun
(Supervisor)

Certified by:

……………………………………   ………………………………
Dr. Prince Osei-Wusu Adjei
(Head of Department)

ABSTRACT

Climate variability is one of the serious environmental challenges that has received a lot of public outcry in most parts of the world due to its consequence on agriculture, energy and industry. This study therefore sought to tease out the effects of climate variability on tomato crop production in the Offinso North District of the Ashanti Region of Ghana. Structured interview guide, focus group discussion guide, in-depth interview guide and participant observation were instruments for data collection covering 378 tomato farmers randomly selected from three communities in the study area. The result of the study suggests an increase in both maximum and minimum temperatures coupled with unreliable rainfall distribution over the last two decades as the cause. The study identified poor yield as a major effect of climate variability on tomato production as reported by the farmers in the District. A regression analysis indicated the significant effect of the climate variables (temperature and rainfall) on tomato production while controlling other confounding variables. It was also observed that in the wake of climate variability and risks, farmers in the study area employ several adaptation strategies to absorb the shock. It is recommended that heat resistant tomato crop that can withstand the pressures of the climatic variations especially high temperatures be developed by the Crops Research Institute of Ghana.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

ADRA	Adventist Development Relief Agency
ANOVA	Analysis of Variance
AR	Assessment Report
ATA	Action Theory of Adaptation
CM	Centimeters
CODAPEC	Cocoa Pests and Diseases Control Programme
CRIG	Cocoa Research Institute of Ghana
CRI	Crops Research Institute
CSIR	Center for Scientific and Industrial Research
DHD	District Health Directorate
DWSP	District Water and Sanitation Plan
DRC	Democratic Republic of Congo
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IBM	International Business Machine
IDA	International Development Association
IPCC	Intergovernmental Panel on Climate Change
JHS	Junior High School
KM	Kilometer
MM	Millimeters
MDG	Millennium Development Goal

MoFA	Ministry of Food and Agriculture
NAAS	National Academy of Agricultural Science
NGO	Non-Governmental Organisation
N-P-K	Nitrogen, Phosphorus and Potassium
ONDA	Offinso North District Assembly
PHC	Public Health Center
SPSS	Statistical Package for Service Solution
TWN	Third World Network
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USHCN	United States Historical Climatology Network
UNDP	United Nations Development Programme
VIF	Variance Inflation Factor

DEDICATION

To my lovely mum Ms. Cordilia Mwaale.

ACKNOWLEDGEMENTS

I wish to extend my profound gratitude to the Almighty God under whose grace and protection I was able to traverse this programme successfully. I am particularly grateful to my supervisors and mentors, Mr. Felix Asante and Dr. Gabriel Eshun for their invaluable guidance, dedication and encouragement throughout this journey.

I sincerely thank the Head of Department, Dr. Prince Osei-Wusu Adjei and all Senior Members of the Department for their indispensable comments and inputs which helped shape the work. I am also indebted to all the Postgraduate students in the department who motivated me to complete this research.

I am most grateful to my wife, Ms. Vida Asantewaa Boateng, for her moral support throughout my programme of study. I am thankful to Mr. Mathew Bakiteh, Mr. Denis Nti, Mr. Enoch Asare, Mr. John Anane, Mr. Isaac Normanyo, Mr. Isaac Adjei, Mr Jacob Arhin (All of New Edubiase Senior High) and Mr. George Digle for their incredible support and inspiration. I honestly thank Kujo Sampson, Gape Daniel and Emmanuel Yamoah for helping me during the data collection exercise. I wish to say a big thank you to my dear sister, Mercy Guodaar for her financial support and motivation.

Finally, I appreciate the support of my family members and friends as well as loved ones. It is my prayer that the Lord Jesus Christ will continue to position you well on the trajectory of grace, Amen.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

One of the biggest environmental challenges that is bedeviling mankind in this 21st century is the changing climate across the globe (Datta, 2013). The magnitude of impact of the phenomena cannot be underestimated as it has the propensity to affect the output of most agricultural crops, including vegetables (Lee *et al*., 2012; Kemausuor *et al*., 2011 and Kotir, 2011). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) has strongly given an indication to the effect that the changing climate is "unequivocal", and "unprecedented" since the mid- 20th century (IPCC, 2014). The degree of impact of the changing climate may have accelerated the inconclusive debate and research by scientists about the causes and consequences of the phenomenon and the need to develop coping or adaptive strategies.

The IPCC through its series of assessment reports including the latest Fifth Assessment Report established that global climate is changing as a result of the combined anthropogenic forces due to Greenhouse Gases (GHG), which are emitted into the earth‟s atmosphere. Even though several GHG such as methane and nitrous oxide are recognised as major greenhouse gases in the atmosphere, it is convincingly argued that carbon dioxide is one of the most anthropogenically produced greenhouse gases that causes warming of the atmosphere (United Nations Framework Convention on Climate Change [UNFCC], 2007). According to Tubiello (2012), the annual amount of carbon dioxide emitted into the atmosphere is about 13-15 billion tonnes, about one third of the total emissions from human activities. The presence of carbon dioxide in the atmosphere through human activities (e.g. deforestation, burning of fossil fuels and bad farming practices such as slash and burn) absorb the ultra violet radiation from the sun but prevents it from escaping through the atmosphere. Therefore, carbon dioxide warms the atmosphere and consequently affects the dynamics of climatic variables such as temperature and precipitation.

In view of the emissions of these greenhouse gases in the atmosphere, crops and forage plants continue to be subjected to the mercy of the increasing temperatures and changing precipitation patterns with the cumulative effects of reduced plant growth and yield (Walthall *et al*., 2012). The IPCC projections and regional level studies suggest that a changing climate is likely to impact agricultural production, adversely affect human health through climate induced heat stresses and diseases as well as altering the hydrological cycle in countries such as East and Southeast Asia (IPCC, 2012). The implication is that, if the climate keeps changing without the development of cutting-edge technologies to respond to the situation, it may cause food insecurity and poverty especially, among food crop farmers in eastern and south-eastern parts of Asia.

Temperature and precipitation are two most important climate parameters that are most studied in climate research because of their immediate impact in various socioeconomic sectors (e.g. agriculture and hydrology), including human comfort (Sayemuzzaman *et al*., 2014). Temperature and rainfall have therefore become important variables which can have direct and indirect effects on agricultural crops in general. To Datta (2013), temperature increase and erratic rainfall patterns are two major parameters that have affected the production of a vegetable crop like black pepper in India. Increases in temperature coupled with more precipitation variations as a result of the changing climate, reduce productivity of crops, and these effects outweigh the benefits of increasing carbon dioxide (Walthall *et al*., 2012).

According to Lee *et al*. (2012), the elasticity of annual climate variables indicates that warmer temperatures significantly decrease agricultural production including crops in Asia. It is estimated that when annual mean temperature increases by 1 percent, average agricultural production decreases by 0.346 percent. Also, the study of Waithaka *et al.* (2013) using crop modeling assessments of the potential effects of climate change have shown yield losses of maize in most parts of the Democratic Republic of Congo, Ethiopia, Tanzania, and northern Uganda. However, the study also shows an increase of sorghum yields in the western DRC, the highlands of Ethiopia, Kenya, Sudan, and Tanzania. Moreover, the study of Ayanlade *et al.* (2010) on the impact of climate variability on tuber crops in the Guinea Savanna part of Nigeria supports the extent to which climate variability affects crop production. According to their study, rainfall variability caused a reduction in yam yield during the periods of 1990/1991 in Nigeria.

Along similar lines, Lobell *et al.* (2011) cited in Chijioke (2011) argue that, for each degree that a crop spends above 30^{o}C, there was a reduction of yield by 1 percent. They further revealed that, the availability of water has an important effect on the sensitivity of crops with yields decreasing by 1.7 percent for each degree day spent over 30^{o}C under drought conditions. Extreme climate conditions, such as dry spells, sustained drought, and heat waves have been projected to have large effects on crops and livestock production (Walthall *et al*., 2012). Again, it has also been revealed that high temperatures impact on vegetable crops like lettuce, carrot and cucumber to the extent that the high temperatures suppress bisexual flowers, decrease the number of flowers and inhibit flower differentiation and development, which result in low yield (Masahumi *et al.*, 2011).

It is also important to emphasise the fact that extreme climatic events such as protracted drought and flooding have greater potential of adversely impacting on agricultural crops through the creation of favourable conditions for the growth of pest and diseases which attack these crops and reduce the amount of yield received (Garrett *et al.*, 2013). Since extreme climatic events are limiting factors to agricultural production, the manifestation of these extreme events of climate may potentially affect crops at every stage of production (from cultivation to harvesting period). Protracted drought reduces the soil moisture content and promotes evapotranspiration which eventually reduces the growth and yield of crops. For instance, droughts and floods have been reported to cause failure and damage to agricultural crops and livestock culminating to lingering food shortage (Mary and Majule, 2009). At the global level, the impact of climate variability is much felt by developing countries (IPCC, 2014). The argument is that, developing countries that produce less carbon dioxide do not wield the requisite capacity in terms of technology to respond to the varying climate as compared to the developed world that produce significant amount of carbon dioxide but possess the technological capacity to respond to the effects of the phenomenon.

Sub-Saharan Africa (SSA) has been professed as one of the regions that is vulnerable to the effect of global climate change as a result of its reliance on agriculture which is highly sensitive to weather and climate variables such as temperature, precipitation, light and extreme events and the low capacity for adaptation (Kotir, 2011). Even though there is a moderate increase in the length of crop growing period in some patches of the region (i.e. Eastern Africa), agricultural productivity could decline dramatically due to climate change in the decades ahead as temperatures increase and rainfall patterns change (Oxfam, 2011). For instance, the findings from a study conducted by Awotoye and Matthew (2010) on the impact of the changing climate on crop yield from 1991-

2006 in South-Western Nigeria revealed that, temperature and rainfall have significant impact on crop yield. From their study, crop yield increased when there was enough rainfall and decreased when mean temperature increased. High temperatures increase evaporation and reduce the moisture content in the soil thereby affecting plant growth.

Empirical evidence in Africa supports the impact of the varying climate on crop production. Research on the impacts of climate change in Zimbabwe shows that the country‟s agricultural sector which includes vegetable production is already suffering from changing rainfall patterns, temperature increases and more extreme weather events, like floods and droughts (Manyeruke *et al.*, 2013). The situation is not different in Ghana as research continues to establish the impact of climate change on crops. The findings of researchers at the International Food Policy Research Institute (IFPRI) on the impact of climate change on yields of crops reveals an overall decrease in yields of all the crops (e.g. maize, groundnut, yam etc.) in the deciduous forest (Nutsukpo *et al.*, forthcoming cited in Pinto *et al.*, 2012). Deuter (2008) summarises the impacts of climate change on vegetables as follows:

- changes in time to harvest for some crops and locations ;
- changes in the suitability and availability of cultivars for current and future production locations;
- reduced availability and increased cost of irrigation water in most locations and in some seasons;
- greater seasonal variability;
- increased pest and disease incidence and „new‟ pests, diseases and weeds;
- damage from extreme events (e.g. rain, hail, wind and heat stress); and

- negative impacts on soils and crops due to extreme temperature and rainfall events and flooding.

At the local level, it is argued that the agricultural sector is the most vulnerable of all the other sectors. According to Sofoluwe *et al.* (2013) cited in Owombo *et al*. (2013), climate variability is the most important limiting factor to agricultural production that can cause serious threat to the sustainability of food production. However, it is important to note that the vulnerability of the agricultural sector is due to its reliance on rainfall (Walthall *et al*., 2012).

As a result of the impact of changing climate on agricultural production, the debate has now shifted from high level advocacy on "the need to act" to country and regional level responses on "how to adapt" (Wilby, 2007 cited in Bagamba *et al*., 2012). It is in the light of this that farmers in various countries continue to develop strategies to cope with the stress and damage the changing climate can impose on the countries agricultural sector (Pinto *et al.*, 2012). Thomas Staal, the mission director for the United State Agency for International Development (USAID) Africa Bureau, during the seventh African Development Forum in Addis Ababa in 2010, reiterated the need for countries to employ science and technological innovation in adapting to the climate change situation (Sarr, 2010). The application of coping strategies varies from farmer to farmer depending on the type of crop, the type of soil and the resources available to the farmer. Beside farmers" efforts to adapt to the changing climate, governments through its institutions are also seeking ways of fashioning out policies to mitigate the impact to prevent food insecurity. The development and implementation of adaptation strategies will go a long way to help offset the unpredictable nature of the climate in order to sustain food production.

Agriculture is indeed considered as the backbone of most economies, especially in developing countries, including Ghana. The contribution of agriculture to the socioeconomic development of Ghana cannot be under-estimated. According to the Ministry of Food and Agriculture (MoFA), the crop sub sector contributes about 66.2 percent of the Gross Domestic Product (GDP) of the agricultural sector in Ghana (MoFA, 2010). This sub sector includes tomato production which is heavily cultivated in the Offinso North District. Tomato is a popular food item in the study area and Ghana in general with an overall consumption rate of 25,000 tons a year at a total cost of about US$25 million (Tampoare, 2012).

Tomato (*Lycopersicon esculentum*) is one of the major consumed vegetables that supply the body with vitamins A, B and C, iron and phosphorus on a daily basis by many households in the Offinso North district. Interestingly, most traditional staple foods consumed in the country lack some of these vital minerals. Again, epidemiological studies reinforce the fact that the consumption of tomatoes can go a long way to reduce the occurrence of human prostate cancer (Kotake-Nara *et al*., 2001). Moreover, tomato production is also an important source of income to most smallholder farmers in the Offinso North District which provides them the opportunity to take up some social responsibilities in the family. In view of the relevance of tomato to the socio-economic development of the country, Ghana, there is the urgent need for research to be conducted to see how best we can help sustain food production through the production of more tomatoes in the sub-region to meet the urgent need of the society.

1.2 PROBLEM STATEMENT

According to reports by the District Directorate of MoFA, rising temperature and erratic rainfall pattern which are attributed to the varying climate have been the bane of the tomato farmers. The variability of the climate in recent times has led to a reduction in tomato yield with less than 10 tons per hectare in Ghana (Robinson and Kolavalli, 2010). Unfortunately, the Offinso North District happens to be one of the localities in the country that is vulnerable to climate variability and has suffered reduction in tomato yield over the years as a result of the changing climate. Since the reduction in tomato production is a threat to food security with the potential to contribute to the risk of famine, there is the need for a comprehensive research to explore the extent of the effect of the climate variability on tomato production.

A reconnaissance survey conducted by the researcher in the study area revealed that, erratic rainfall pattern and high temperatures are some of the major problems affecting tomato farmers in the district.

The effect of the low yield in tomato production partly attributed to the varying climate in the study area and the country at large may have necessitated the recent importation of fresh tomatoes from neighbouring countries especially Burkina Faso to supplement what is locally produced (Horna *et al.*, 2006).

Extreme climatic events such as floods and drought have greater adverse effects on tomato production (Bita and Gerats, 2013). Higher temperatures adversely affect soil moisture, while prolonged droughts and increasing temperatures create favourable conditions for pests and diseases to multiply thereby reducing crop yield (Garrett *et al.*, 2013). The overall effect of these extreme climatic events is the reduction of plant growth which adversely affects the yield of most vegetable crops, especially tomato which is very sensitive to temperature and rainfall variation.

Also, tomato cultivation is a source of livelihood to most farmers in the district and since tomato cultivation is rain-fed, the erratic rainfall pattern and high temperatures in the area has the potential to threaten the livelihoods of these farmers. Research evidence suggests that food production and related livelihoods will be disproportionately affected by climate variability and change in sub-Saharan Africa (Schlenker and Lobell, 2010).

Even though there seem to be much research regarding the impact of climate variability and change on agriculture (Awotoye and Matthew, 2010; Malla, 2008; Codjoe and Owusu, 2011), very little information is available in the area of climate variability and vegetable production, especially tomato in Ghana and the study area in particular, which is noted for its large scale production of tomatoes. The issues discussed thus far raise a number of questions which is the subject of the next subsection.

1.3 RESEARCH QUESTIONS

The study sought to find answers to the following questions:

- What has been the trend of climate variability over the past 20 years (1994-2013) in the Offinso North District of Ghana?
- How does climatic variation affect tomato production in the district?
- How do the farmers perceive the effects of climate variability on tomato production?
- What are the adaptation strategies of the farmers in response to the effects of climate variability?

1.4 RESEARCH OBJECTIVES

The primary objective of the study was to assess the effects of climate variability on tomato crop production in the Offinso North District.

Specifically, the study sought to:

- Analyse the trend of climate variability over the past 20 years (1994-2013) in the Offinso North District, Ghana;
- Examine how climatic variations affect tomato production;
- Investigate how the farmers perceive the effects of climate variability on tomato production; and
- Assess the current adaptation strategies of the farmers in response to the effects of climate variability.

1.5 RESEARCH HYPOTHESES

The study tested the following hypotheses:

H_0: There is no significant relationship between temperature and tomato yield.

H_1: There is a significant relationship between temperature and tomato yield.

H_0: There is no significant relationship between rainfall and tomato yield.

H_1: There is a significant relationship between rainfall and tomato yield.

H_0: There is no significant relationship between the sex of farmers and their perception of the effects of climate variability.

H_1: There is a significant relationship between the sex of farmers and their perception of the effects of climate variability.

1.6 SCOPE OF THE STUDY

The study was designed to assess the effects of climate variability on tomato crop production and farmers adaptation strategies in response to the effects. Geographically, the study was designed to cover the Offinso North District which is vulnerable to climate variability with a lot of the people cultivating tomato for their livelihood (ONDA, 2013). The study involved three communities (Akomadan, Afrancho and Nkenkaasu) that produce a greater percentage of the tomato in the district. Contextually, the study analysed the trend of climate variability over the past twenty years (1994-2013) as well as how climatic variations affect tomato production in the Offinso North District. The study also investigated how the farmers perceive the effects of climate variability on tomato production and finally assesses the current adaptation strategies of the farmers in response to the effects of climate variability.

1.7 JUSTIFICATION FOR THE STUDY

The study will go a long way to improve the methodological strand of previous studies. The quantitative approach has been adopted by previous researchers in finding out the effects of climate variability on crop production (Traore *et al.*, 2013; Awotoye and Matthew, 2010 and Tshiala and Olwoch, 2010). However, the deficiency associated with this particular approach is that, it emphasises the breadth of the study rather than the depth (Creswell, 2010). It is in the light of this that this research employs the mixed methodology to add a qualitative dimension to the already used quantitative approach to help address the problem holistically.

Also, Tshiala and Olwoch"s (2010) study on the effects of climate variability on tomato production in the Limpopo Province in South Africa, used temperature as the only variable to determine the impact of climate variability on tomato production with an important variable like rainfall being relegated to the background. However, the relevance of rainfall cannot be underestimated because tomato needs considerable amount of water to survive. This deficiency in the work of Tshiala and Olwoch (2010) creates a lacuna in literature which the study intends to fill by exploring how rainfall and its variability could also impact tomato production.

Furthermore, the study will serve as a useful reference material to future researchers who would want to research into similar area. The study will therefore serve as an important document that will guide prospective researchers in their quest to researching into areas related to climate variability impact and adaptation. Finally, even though research on adaptation to climate variability seems to be on the increase there is still the need to conduct further research to enable the sharing of different adaptive strategies adopted by farmers at different places. This analysis will go a long way to influence policy makers to enable them document effective adaptive strategies that will help reduce the negative effect of climate variability on rural farming communities, especially those with similar environmental characteristics.

1.8 LIMITATIONS OF THE STUDY

The intention of the researcher was to cover more communities in the district. However, due to financial constraints and time factor, it was not possible to cover most of the communities in the study area. Again, it was quite difficult getting climate data from the weather station and tomato production data from the District Directorate of MoFA due to the amount of financial resources involved. This problem was overcome through the assistance of family members who assisted the researcher with some finance.

Also, tomato farmers who had registered with the District Directorate of MoFA in the year 2015 were not considered for the study. The sampling of the farmers was only based on those who had registered up to the end of 2014. This potentially affected the total sample size which could have been more representative. However, it is important to note that the total sample size used for the study was representative enough to make generalisations.

1.9 ORGANISATION OF THE STUDY

The study was organised under six major chapters with each chapter linking the successive one. Chapter one comprises the introductory aspect of the study which outlines the background of the study. The chapter also looks at the statement of the problem and the justification for the study. Also, the chapter provides an outline of the general objective with specific objectives clearly defined. This chapter also entails the hypotheses to be tested as well as the scope of the study. The section also explains the limitations of the study and ends with the general organisation of the study.

The second chapter provides a critical review of relevant literature on climate variability. The section encapsulates a review of both empirical and theoretical studies on the trend and effects of climate variability on crop production as well as perceptions and adaptation strategies in response to the effects of climate variability. Finally, a theoretical and conceptual framework for the study is clearly explained with appropriate diagrams. The relevance of this section provides a comprehensive framework that guides the methodology, analyses and recommendations that are in the subsequent chapters.

The third chapter presents the research method employed. It includes the population and sample size, sample and sampling procedure, research design, instrument for data collection, procedure for data collection and data analyses. The section also puts into perspective, the profile of the study area. Some of the relevant elements include the biophysical and socio-demographic characteristics of the area, the built environment and economic and livelihood activities in the area.

Chapter four provides a clear description and presentation of the results on the analysis of the socio-demographic characteristics of respondents. This chapter again looks at the trend analysis of temperature and rainfall as well as the effects of climate variability on tomato production.

The fifth chapter deals with the analysis of farmers‟ perceptions of climate variability effects on tomato as well as the various adaptation strategies they employ in response to the climatic variability effects. Appropriate tables and graphical representations have been used to present an appreciation of the results.

Finally, the sixth chapter presents the summary of key findings, conclusion and recommendations. This chapter also highlights areas for further studies by researchers who are interested in climate variability issues.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter aims at placing the study under a scholarly context by reviewing the various contributions made by several authorities and researchers on climate variability and tomato crop production. This chapter seeks to unearth the various views held by scholars on the nexus between climate variability and tomato crop production. These enabled the researcher to put the problem in its right perspective and hence, provide a better understanding and appreciation of the problem under investigation. Issues and concepts of climate variability and tomato production are theoretically and empirically reviewed.

This chapter is organised into eight sections. Section 2.2 provides definitions and explanations to key climatic concepts such as climate change, climate variability and climate adaptation. Section 2.3 explores global climate variability trends with specific reference to temperature and rainfall variability. The third section, 2.4, provides an overview of tomato production in Ghana with emphasis on the varieties and climatic conditions that favour the cultivation of tomato in Ghana. Section 2.5 presents the nexus between the major climatic variables (temperature and rainfall) as well as extreme climatic events and crop production. Also, sections 2.6 and 2.7 explore the perceptions of farmers about the effects of climate variability and the various adaptation strategies adopted in response to the climate variability risks. Section 2.8 delves into the theoretical framework of the study with section 2.9 finally summarising the literature review.

2.2 DEFINITIONS AND EXPLANATIONS OF CLIMATE CONCEPTS

2.2.1 Climate variability

Climate variability refers to the spatio-temporal variation of climatic conditions beyond individual weather events (Christensen *et al*., 2007). Similarly, Houghton *et al*. (2001) also define climate variability as the variations in the mean state and other statistical descriptions of extreme climatic condition on all temporal and spatial scales beyond that of individual weather events. With regards to the definition by Houghton *et al*. (2001), climate variability is seen as the climatic parameter of a region varying from its long-term mean. Again, emphasis is also placed on the significance of spatiotemporal scales of weather events. The IPCC's (2007) definition of climate variability is in consonance with that of Houghton *et al*. (2001) with emphasis placed on the dimensions of the variability. Two major dimensions of climate variability are identified: internal variability and external variability. The internal variability looks at the natural internal processes within the climate system while the external variability emphasises the human induced external forcings that influence the climate (IPCC, 2007).

In the words of Lobell (2010), high climatic variability represents a delicate balance between agricultural production and food security. Lobell further opines that the changes in the agriculturally-relevant variables of climate (e.g. increasing temperatures and declining levels and distribution of rainfall), are likely to reduce yields of crops such as maize, rice, among others in semi-arid regions of the world.

Lobell‟s definition emphasises the relationship between rainfall and food production without taking other climatic variables like temperature into consideration. From the various scholarly definitions of climate variability, the phenomenon is operationally referred to as the oscillations and dynamics of the various climatic elements which have resulted from either natural or anthropogenic means over a longer period of time for at least ten years.

2.2.2 Climate change

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2014). The element of duration clearly distinguishes climate from weather. While weather takes place over a shorter period, climate takes place over a longer period of time. Therefore, the climate is said to have changed when it varies over a longer period of time. Similarly, Sumelius *et al.* (2009) define climate change as a change in the state of the climate measured by changes in the mean and in the variability of certain properties (e.g. temperature and precipitation) that persist over decades and that can be detected e.g. by statistical tests. It is important to know that, there are other important climatic elements like sunshine, wind and humidity which also influence climate in one way or the other.

However, as opined by Sayemuzzaman *et al.* (2014), temperature and rainfall are the two most important variables that influence plant growth. According to the United Nations Framework Convention on Climate Change [UNFCCC] (2007), the climate is said to have changed when there is a direct or indirect alteration of the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (IPCC, 2014). However, Arku (2013) defines climate change as any change in climate over time, whether it is the product of natural factors, human activity or both. A cursory look at Arku‟s definition indicates that, apart from the anthropogenic factors which can cause the climate to change, there are other natural factors which can also influence the climate to change. He also emphasises the combined effect of natural and anthropogenic factors that influence climatic changes. This is in line with the argument put forward by the IPCC on the causes of climate change through its fifth assessment report. According to the report, climate change may be attributed to the natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Much emphasis is therefore laid on the anthropogenic factors causing climate change with little information on the natural causes of climate change. Operationally, climate change as used in this work refers to „the resultant effect of climate variability which is either anthropogenic or natural‟.

2.2.3 Climate adaptation

According to the IPCC (2014), adaptation to climate change refers to the process of adjustment to the actual or expected climate and its effects. It further explains that, in human systems, adaptation seeks to cause a reduction in the harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. On the same wavelength, the UNFCCC (2009) cited in SAGUN (2009), defines climate adaptation as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Similarly, the IPCC (2007) defines climate adaptation as initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.

Fussel and Klein (2002) however, share a different view when they defined climate adaptation as all changes in a system, compared to a reference case that reduces the adverse effects of climate change. Adaptation can therefore be regarded as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. This means that an individual has a number of opportunities and options to adapt to a condition, especially an environmental condition. Climate adaptation can therefore be summed as the set of actions, strategies, processes and policies that respond to actual or expected climate changes so that the consequences for individuals, communities and economy are minimised (Pinto *et al.*, 2012). Operationally, climate adaptation as used in this work refers to the various strategies adopted to respond to harsh climatic conditions.

2.3 GLOBAL TRENDS OF CLIMATE VARIABILITY

2.3.1 Introduction

Global trends of temperature and rainfall point to the fact the climate is changing. Mean annual temperatures have been increasing and places in Sub-Saharan Africa and Asia continue to experience weather extremes like flood and drought respectively. With global warming not a hiding secret whether caused by natural variability or anthropogenically induced (IPCC, 2007), it is important to be informed and regularly updated on observed regional temperature and precipitation trends at both regional and local levels. The IPCC (2014) has projected that, if measures are not taken to reduce the generation of GHG emissions, future temperature will continue to increase as well as extreme weather conditions such as drought in most parts of the world especially, countries in Sub-Saharan Africa.

2.3.2 Evidence of global climate variability

There is evidence to demonstrate that global climate keeps on changing. Statistical variations over the years supports the fact that climate change has been happening over long periods, typically decades (Raman *et al.*, 2011). As a result of anthropogenic factors such as deforestation and burning of fossil fuels, the impacts of climate variability have already been observed from rising sea levels to melting snow and ice through to changing weather patterns. According to the IPCC (2007) cited in Sarker (2012), global temperature increase coupled with sea level rise and diminishing Arctic sea ice are evidence that give credence to the fact that global climate is changing. However, the evidence given by the IPCC failed to actually look at the extreme events which have also occurred as a result of the changing climate. For instance, global sea level has increased by 12-22 centimeters (cm) during the 20th century, but satellite records confirm that the rate of sea level rise has now almost doubled to about 3.4 millimeters (mm) per year (IPCC, 2007).

Long-term temperature records from ice sheets, glaciers, lake sediments, corals, tree rings, and historical documents clearly show a more warming condition than the preceding decades in the 20th century (Hansen *et al.*, 2012). Some of the extreme events include; flood and drought conditions that are characterised by climate variability and change. The variations in the global surface temperature and carbon dioxide concentration show how the climate has been changing over time and the likely consequences on the various sectors of the economy especially, the agricultural sector which is more vulnerable (Walthall *et al*., 2012). Mitchell *et al.* (2000) on the contrary found no evidence of a substantial acceleration of sea level rise, in contrast to expectations from global circulation models.

2.3.3 Temperature variability trend

Climate trends and climatic extreme indices derived from empirical, observed data indicate that global average surface temperatures have been increasing since the mid19th century with the greatest rate of change observable since the mid-1970s (IPCC, 2014). This may be attributed to the continuous generation of greenhouse gases through human activities. The recent report of the IPCC reiterates the fact that, anthropogenic factors remain a major cause of recent global warming. Due to the concentration of the greenhouse gases in the atmosphere, temperature continues to rise through the greenhouse effect and this has potentially contributed to the alteration of the rainfall pattern across the globe. Recent climatological studies have shown an increase in global surface air temperature by 0.76°C from 1850 to 2005 (Bakri and Abou-Shleel, 2013). The study reveals the extent to which global temperatures increased over the last century. However, it fails to add to the discourse about the causes of the phenomenon which is fundamentally critical in analysing issues of climate variability and change.

A research carried out by Poulter *et al.* (2013) in the inner Asia which includes the semi-arid regions of northern China, Mongolia, and parts of southern Russia reveals an increase in mean annual air temperature. A similar research conducted by Cinco *et al*. (2014) on temperature anomalies in the Philippines for the period 1951–2010 against the baseline period of 1961–1990 demonstrates an overall increasing trend with values becoming positive in 1977 and „peaking‟ in 1998 with a +1.0 °C anomaly. From 1996 to 2010, the end of the observed period, positive anomalies were consistently greater than 0.5 °C with 2005 and 2006 marking the peak warm years of the first decade of the 21st century. The temperature anomaly as revealed in the research gives evidence which is consistent with a warming global climate. Further studies in Asia have also shown an increase in mean annual temperature. For instance, according to a study by Chen *et al*. (2014), the mean annual temperature (MAT) in the whole Yangtze basin of China over the period 1955–2011 was 14.0^{o}C ranging from 13.4^{o}C to 14.9^{o}C. The MAT increased from 12.7^{o}C in the upper section of the catchment to 16.0^{o}C in the lower basin. The study shows a variation in the increase in the annual mean temperature of the upper and lower basins.

Boyles and Raman (2003) cited in Sayemuzzaman, *et al.* (2014), studied temperature and precipitation trends on seasonal and annual time scales in North Carolina, United States between 1949–1998. The study analysed, using the linear time series slopes to investigate the spatial and temporal trends of precipitation. The study in the final analysis revealed a warmer temperature trend during the 1990s and the warmest being 1950. It can be noted from the analysis that, even though temperature increased within the stipulated duration, the early years experienced much more increase than the latter years and hence, temperature increased at a decreasing rate.

On the contrary, Kruger and Shongwe (2004) argue that, there has not been any gradual increase regarding the annual mean temperature trends. According to them, the average mean temperature of two periods, 1960 to 1990 and 1960 to 2003 did not show much difference in terms of the trends of the two periods. Their conclusion was that, between the periods of 1960 to 1990, the average mean temperature was 18.18^{o}C with a trend of 0.11°C whereas the period 1991 to 2003 had an average mean temperature of 18.48°C and a trend of 0.09°C per decade. Therefore, their argument was that the trend for the latter period was slightly lower than that of the former which meant that temperatures have not been increasing as earlier argued.

Based on the trends of the varying climate over the past decade, the average temperature in Ghana from the period 2010 to 2050 is predicted to range between 34°C (Forest region, Ghana wet scenario) and 41°C (Northern Savannah, Ghana Dry scenario) (World Bank, 2009). This evidence shows that the climatic trend in most part of the world especially, Sub-Sahara Africa keeps on drifting to the negative with its effects on the environment and agricultural production. It is therefore important that farmers within the Sub-region be given the needed empowerment to be able to implement effective adaptation strategies to help respond or reduce the impact of the varying climate. Similarly, a significant linear increase in mean annual air temperature occurred between 1960 and 2001 along the coast of Ghana of about 0.9°C; the maximum and minimum temperatures increased by 2.5 and 2.2°C, respectively, during this time sea-surface temperatures showed a slight but nonsignificant increase during this period (Dontwi *et al.*, 2008). Moreover, it is further projected that, countries are expected to experience an increase in average temperature overall by 1°C by 2030 and by 1.4°C by 2050 (IPCC, 2007). In a similar direction, eco-climatic zone projection of mean annual temperature in most part of Ghana is projected to increase significantly within 30 years interval from 1920, 1950 and 1980 with a corresponding temperature increase of 0.6, 2.0 and 3.9-4.0^{o}C (Minia, 2008). These projections of climatic trends therefore make it imperative for more research to be conducted to help ameliorate the problem.

2.3.4 Rainfall variability trend

The study of Chen *et al*. (2014) indicates that precipitation across the whole Yangtze basin of China is very high in comparison to many rivers elsewhere. Annual precipitation across the whole basin averages 1024 mm and even in the driest section,

the upper basin, the average is still 854 mm. The study however attributes the high precipitation in the Yangtze basin to the relatively small net consumption of water in relation to total annual flow in the region. In the same vein, Petrie *et al.* (2014) demonstrated in their study at northern Chihuahuan Desert, United States, that regional precipitation exhibits trends in average event timing and magnitude. Their study however indicated that the compensating changes did not induce change in the total average monsoon precipitation at the United States Historical Climatology Network (USHCN) sites over the last 100 years. The major reason given for no change in average total precipitation was explained to the effect that small number of very large events could account for the majority of total precipitation and that smaller events may often be insignificant in terms of total precipitation. Contrary, the findings of Afzal (2011) reveals that the increasing trends in rainfall have not been temporally continuous. Rather, the findings show an abrupt change in precipitation amounts around 1980 in Western Scotland. The study further notes that there was a spatial pattern in average rainfall variability. For instance, the West and South-west regions experienced the highest rainfall variability pattern. The study is deficient as to why the increasing trend in rainfall has not been temporally continuous. In the analysis of
Tao *et al.* (2011) on the characteristics of hydro-climatic changes in the Tarim River Basin in China. They noted that the stations with significant increasing trends in annual stream flow were mainly distributed at the southern slope of Tianshan Mountain, which can only be explained by climatic changes.

Lionello *et al.* (2011) therefore confirm the absence of important sustained trends of severe marine storminess in the northern Adriatic during the second half of the 20th century by the analysis of hourly sea level time series and significant wave height records. Even though the study shows some relatively negative trends, the time series methodology employed were dominated by large inter-annual variability. The study further avers that cyclones which produce extreme storm surges differ from those producing high waves, and both have specific characteristics that distinguish them with respect to other cyclones passing over northern Italy.

According to Jidauna *et al*. (2011), the quantity and duration of rainfall pattern experienced over the years in Nigeria remarkably decreased by 78.6 percent while the intensity of the rains experienced in the rainy season also decreased by 77.3 percent. Again, according to the study, the stream flow data over the past twenty years in Nigeria shows a decrease in rainfall of about 76.8 percent affecting the level of stream flow and time of annual recharge. It is therefore clear that such a considerable reduction in rainfall has the potential to impact significantly on agriculture with an overall consequence on food security. The situation was not different from the situation around the coastal areas of Benin as the analysis of climate data recorded for the last 40 years as well as the climate model implementation showed a decrease of annual rainfall pattern and the shortening of the rainy seasons (Teka *et al.*, 2010).

In the case of Ghana, research has revealed that the annual rainfall in the country is highly variable on inter-annual and inter- decadal timescales, making identification of long-term trends difficult. However, in the 1960s, rainfall in Ghana was particularly high and decreased to particularly low levels in the late 1970s and early 1980s. This caused an overall country-wide decreasing trend in the period 1960 to 2006 of an average 2.3mm/month (2.4 percent)/decade (McSweeney *et al.*, 2008). In addition, another study conducted by Dontwi *et al*. (2008) with specific reference to the Coastal areas in Ghana shows a significant linear decrease trend from 1961 to 2000 (decrease of about 1000 mm) with a marked cycling of high and low rainfall years with an apparent six-year lag. Comparison of the mean annual rainfall differences between 1951-1970 and 1981-2000 at meteorological stations across Ghana also indicate less rainfall (Owusu and Waylen, 2009 cited in Stanturf *et al.*, 2011). The reduction of rainfall in Ghana between the periods of 1981-2000 may have partly stemmed from the severe drought condition experienced in 1983, which culminated in hunger and famine in the country with most people travelling to other parts of the world. The reduction in rainfall did not only affect the flora but it also affected fauna and aquatic species. Again, the reduction in rainfall goes a long way to affect plant growth. There is therefore the fear that, the reduction in rainfall among countries in Sub Saharan Africa may continue to worsen, the food security situation since most of the crops cultivated on the continent are rain-fed.

2.4 TOMATO CROP PRODUCTION IN GHANA

Tomato (*Lycopersicon esculentum*) is one of the vegetables that is produced in Ghana and contributes immensely to the socio-economic development of the country. Tomato is widely produced in the Northern, Upper East and Southern Volta Regions of Ghana as well as notable areas in the middle belt such as the Offinso North and Wenchi districts of the Ashanti and Brong Ahafo Regions respectively (Third World Network [TWN], 2007). The tomato crop is cultivated throughout the year due to the fact that, beside the rain-fed system that normally stretches between June and November in the southern part of the country, there is the dry-season system between October and April mainly in the north, especially in the Upper East region (Asante *et al.*, 2013). There are vast arable lands for the cultivation of tomato in Ghana. Most farmers in the Offinso North District cultivate tomato as one of their crops grown. Apart from the provision of livelihood assets to some farmers in the country, tomato also provides important sources of minerals such as vitamin A, B, and C to the body. One medium ripe tomato (~145 grams) can provide up to 40 percent of Vitamin C and 20 percent of Vitamin A (Kelley and Boyhan, 2010). The supply of these minerals helps the body to fight against diseases. Even though domestic tomato production seems to increase in the country, it still does not meet the high demand of the population and this has culminated in the importation of tomatoes from other countries, especially Burkina Faso (Horna *et al.*, 2006).

Tomato needs suitable soil and climatic condition for growth. Even though, tomato can be produced on a variety of soil types, they grow optimally in deep, medium textured sandy loam or loamy, fertile and well-drained soil (Kelley and Boyhan, 2010). The soil provides physical support, nutrients and water to the crop. This means that, in the event where there is deficiency in the afore-mentioned factors, crops will not do well and it will lead to a reduction in yield or production. It is also worth noting that, the provision of support, nutrients and water by soil depends to a larger extent on the topography, soil type, soil structure and soil management practices. For tomato production, there is the need for proper tillage to ensure adequate soil management and improve crop yields. Land preparation should involve enough tillage operations to make the soil suitable for seedling or transplant establishment and to provide the best soil structure for root growth and development (Kelley and Boyhan, 2010).

There are varieties of tomatoes cultivated in Ghana. Some of the local varieties of tomato produced in Ghana include; Raster, Power Rano and Wosowoso, with Power Rano often being preferred due to its high tolerance and/or resistance to diseases (Robinson and Kolavalli, 2010). The local varieties produce large, ridged fruits with thin skin which split and bruise easily. The fruits contain more seeds and the yields are relatively higher under favourable conditions such as adequate moisture, diseasefree conditions, weed control and judicious fertilization (Appiagyei, 2010). There are also some exotic varieties of tomatoes that are cultivated in the country. Some of these exotic varieties are Pectomech, Royal, Marglobe, Marvel, Money-maker, Roma and Fireball. These exotic varieties are generally not suitable for large scale cultivation under traditional systems of management, especially in the more humid areas of the forest zone (Appiagyei, 2010). This is a clear indication that farmers in Ghana cultivate both local and exotic varieties of tomatoes. However, most tomato farmers in Ghana ideally prefer the cultivation of local varieties of tomato to the exotic ones due to the cost involved. Some of the important factors that influence farmers‟ choice of varieties of tomatoes are access to seeds, growing technologies, available markets, potential yields, prices, and risk (Robinson and Kolavalli, 2010).

Even though tomato production seems to be on the increase over the years, yields continue to fall due to several production constraints which include biotic and abiotic factors (Asante *et al.*, 2010). While the abiotic factors look at erratic rainfall, high temperature, and poor soils, among others, the biotic constraints include diseases such as tomato yellow leaf curl virus, bacterial wilt, bacterial spot, early blight, and tomato mosaic viruses (Asante *et al.*, 2010). Climatological extremes, including very high temperatures are predicted to impact negatively on plant growth and development, with an overall effect of catastrophic loss of crop productivity which would have farreaching effects on food production (Bita and Gerats, 2013). On the same wavelength, the IPCC (2007) postulates that increased temperatures are expected to reduce crop yields and increase levels of food insecurity even in the moist tropics. This negative impact of high temperature is expected to increase risks in the agricultural sector (Gornall *et al.*, 2010).

The optimum temperature for favourable tomato growth ranges between 21 ^{o}C and 24 ^{o}C (Attoh *et al.*, 2014) beyond which the tomato crop will be affected with an overall effect on the yield. According to Sinnadurai (1992) tomato does well at day temperatures of 24^0C to 29^0C and night temperatures of 13^0C to 21^0C). Ghartey *et al*. (2012) however, opine that tomato requires a minimum temperature of 15^0C to 20^0C for its survival with a high temperature of 21^0C to 28^0C. During flowering tomato is very sensitive to the air temperature which plays an important part not only when the flowers and pollen are formed, but also during pollination and fertilization (Sinnadurai, 1992). High temperatures usually delay flowering and reduces the number and size of the flowers (Sinnadurai, 1992). Similarly, Kalibbala (2011) reiterates the fact that high temperatures above 27^oC are likely to induce pollen sterility with high night temperatures adversely affecting flower initiations which ultimately affects yield. These abiotic stresses are frequently interconnected, either individually or in combination, they cause morphological, physiological and biochemical changes that seek to impact significantly on the growth of plants and productivity, as well as crop yield (Bita and Gerats, 2013). In view of the various constraints that hinder tomato production in Ghana, there is the need to select varieties of tomato on the basis of adaptability and disease resistance or tolerance (Kelley and Boyhan, 2010).

Kalibbala (2011) opines that excessive rainfall and high relative humidity can be harmful to the tomato crop, due to proliferation of the leaf disease during humid conditions. An annual rainfall of 750 mm evenly distributed is adequate and good for tomato growth (Mensah *et al.*, 2013). This implies that in the event that annual rainfall exceeds the normal or the optimum, 750mm, the crop may suffer. Excessive rainfall therefore reduces light intensity and thus adversely affects the yield as well as increases the incidence of fungal diseases (Mensah *et al.*, 2013). They therefore recommend that where rainfall is found to be erratic, additional irrigation should be given a priority to help boost the yield. On the contrary, Romain (2011) avers that tomato requires a relatively high humidity and longer hours of day light to develop and grow well. The implication is that, low relative humidity can limit the growth of tomatoes and high relative humidity can also impact significantly on tomatoes.

Therefore, there is the need for more education by Agricultural Extension Officers to help equip farmers with such vital information and the need to adopt strategies that will help tomato cultivation.

2.5 THE NEXUS BETWEEN CLIMATE VARIABILITY AND CROP PRODUCTION

2.5.1 Temperature variability and crop production

Globally, especially in developing countries, climate variability cause yield declines for their most important crops (Sudarkodi and Sathyabama, 2011). Temperature is an important element that limits the growth of plants and crops. Some level of relationship therefore seems to exist between temperature and the yields obtain from the cultivation of crops. High temperatures affect some agricultural crops and cause a reduction in yield (Sudarkodi and Sathyabama, 2011) which ultimately impact food security. The study of Deressa and Hassan (2007) using the Recardian model reveals that, a marginal increase in temperature in summer and winter caused a reduction in crop yield and revenue per hectare. The reduction in the yield and income of farmers has significant impact on the livelihoods of the farmers as well as some of the socioeconomic roles they play in the family.

Additionally, Basak (2009) studied the impact of climate variability and change on rice production in Bangladesh using the simulation model. The study showed a drastic reduction in crop yield from 13.5 to 2.6 percent and from 28.7 to 0.11 percent when the maximum temperature was increased by 2°C and 4°C. The model shows that, even though both maximum and minimum temperature cause a reduction in crop yield, the effect of high temperatures on yield is high as compared to the effect of low temperature on yield. According to the IPCC (2012), high temperatures and extreme weather events are predicted to increase in Sub-Sahara Africa and South Asia with a resultant effect on growth and yield of most agricultural crops in these regions which will activate serious concerns about food security. Even though climate warms and minimum average temperatures increase, years that show low maximum temperatures are likely to draw closer to achieving the temperature optimum, which may cause an increase in yield than is the case today during years when average temperatures were below the optimum (Walthall *et al*., 2012). Conversely, Welch *et al.* (2010) exemplified in their study that higher minimum temperatures reduce yields, while higher maximum temperature increases yields. They further explained that maximum temperatures would cause a reduction in yield only when the level of rise is significantly above a critical or optimum level. However, it is important to note that, the impact of high and low temperatures on crops depend on the type of crop under consideration.

Another important area of agriculture that are significantly affected by temperature increase is vegetable crops. Vegetable crops need some optimum amount of temperature for growth and development, and beyond that optimum level crops suffer. For instance, higher temperatures induce floral differentiation and flower stalk development in lettuce plants, both of which decrease yield and quality of the crop; high temperature affects the flowering and development of cucumber and cause a reduction in yield; and high temperatures during flowering induce flower abscission, malformed flowers, and pollen sterility in tomato plants thereby resulting in poor flowering and fruit (Masahumi *et al.*, 2011). Similarly, Datta (2013) emphasised the fact that high temperature can impact significantly on crops and cause a drastic reduction in yield. This therefore reinforces the need to employ adaptation strategies to help cope with the impact.

For vegetables, exposure to temperatures in the range of 1°C to 4°C above optimal for biomass growth moderately reduces yield, and exposure to temperatures more than 5°C to 7°C above optimal often leads to severe, if not total, production losses which affects food availability (Walthall *et al.*, 2012). This means that no matter the degree of temperature, crop yield will reduce to a larger extent. The National Academy of Agricultural Science [NAAS] (2013) reiterates the fact that vegetables mature early, and heavy crop losses will be noted when crops are exposed to abnormal increases in temperature. On the contrary, the study of Welch *et al*. (2012) showed that, high temperature has no adverse effect on crop yield unless the amount of heat is beyond the optimum requirement of the crop.

2.5.2 Rainfall variability and crop production

Vegetable production is influenced by climate variability in the area of rainfall availability (Masahumi *et al*., 2011). Precipitation has a direct relationship with agricultural crops with an increase or decrease in precipitation having impact on yield (Walthall *et al.*, 2012). Kassie *et al.* (2014) opine that rainfall variability does not necessarily affects crop yields directly on water availability but indirectly affect crop yield by limiting the application of agricultural inputs (e.g. fertiliser). For instance, corn is vulnerable to excess water in the early growth stages and can cause a reduction in plant growth, while a reduction in the amount of water in soil leads to less growth and yield if the stress occurs during the grain filling period of growth (Hatfield and Prueger, 2011). The study of Awotoye and Matthew (2010) on the effects of temporal changes in climatic variables on crop production in Nigeria reveals a decrease in yield of sorghum in the year 2000 when rainfall reduced. However, as the amount of rainfall increased in 2002 and 2004, the yield of maize increased. This gives an indication to the effect that increase or decrease in rainfall has a greater propensity of determining the yield of crops especially, grains.

The IPCC uniform climate scenarios show that, a decrease in precipitation of a place will cause a reduction in yield with farmers losing their entire net revenue from crops if precipitation decreases by 14 percent (Kassahun, 2009). Similarly, the study of Molua and Lambi (2006) shows a decrease in net revenues when precipitation decreases or temperature increases across farms in Cameroon. The forgoing studies give credence to the fact that precipitation has some level of influence on crops. While an increase in precipitation causes an increase in crop yield, a reduction in precipitation causes a decline in the net yield of crops especially, crops that need considerable amount of water to survive. There is therefore a direct relationship between precipitation and crop yield. Therefore, in the event of low precipitation, there is the need to resort to irrigation to ensure that crops get the needed amount of water for their growth.

It is important to recognise the fact that, notwithstanding the above impacts climate variability has on crop production, there are some positive effects as well. For instance, Sudarkodi and Sathyabama (2011) opine that the high concentration of atmospheric carbon dioxide which is believed to cause warming conditions and affect crops rather increases photosynthetic activities of crops and increase yield. According to them, the doubling of carbon dioxide increases photosynthetic rates by as much as 30 to 100 percent. Again Lee *et al.* (2012) also aver that high temperatures and very high precipitations in summer increases agricultural production. Even though the dynamics of how high temperature may lead to crop increase is not clear, it is quite clear that an increase in rainfall may lead to an increase in yield especially with crops that need a greater amount of rainfall like rice.

2.5.3 Extreme climatic events and crop production

Droughts and flooding are one of the extreme climatic conditions that hinder the development of most agricultural crops especially, rain-fed agricultural crops. Easterling *et al.* (2000) suggest that the sensitivity of societal infrastructure to extreme climatic events cannot be over-emphasised. For instance, it is explained that extreme conditions (such as droughts, flooding) can have significant effect on crop yields than optimal mean conditions.

Inefficient water usage in most parts of the world and inefficient distribution systems in developing countries cause a considerable reduction in the availability of water. The availability of water to a large extent has high sensitivity to the changing climate with severe water stress conditions affecting crop productivity, especially vegetable crops (Pena and Hughes, 2007). In combination with elevated temperatures, decreased precipitation could cause reduction of irrigation water availability and increase in evapotranspiration, leading to severe crop water-stress conditions (IPCC, 2001). Therefore, water significantly affects the yield and quality of vegetables with drought conditions severely reducing the productivity of vegetables. Drought stress causes an increase of solute concentration in the environment (soil), leading to an osmotic flow of water out of plant cells. This leads to an increase of the solute concentration in plant cells, thereby lowering the water potential and disrupting membranes and cell processes such as photosynthesis (Pena and Hughes, 2007).

Most crops are intolerant to flooding and production is often limited due to the excessive nature of the moisture brought about by torrential rains. Most vegetables are highly sensitive to flooding and genetic variation with respect to this character is limited, particularly in tomato. In general, damage to vegetables by flooding is due to the reduction of oxygen in the root zone which inhibits aerobic processes (Pena and

Hughes, 2007). The overall effect of the reduction in oxygen of plants is that, most crops are likely to suffer severe losses with an adverse effect on food security. For instance, according to Naeve (2002), the effect of flooding for six days may potentially cause a significant depression of yields with longer periods of flooding causing an overall damage to the entire stand.

2.6 EXPLORING LOCAL PERCEPTIONS OF CLIMATE VARIABILITY

2.6.1 Introduction

Majority of people across the globe depend much on the available natural resources for survival, especially the poor, who are often vulnerable to climate variability and change (Morton, 2007). This therefore brings to the fore the need to understand and appreciate how local people in communities experience and respond to such variability that would help them to devise effective coping strategies. "Local perceptions" as used in this work refers to the manner by which local people identify and interpret observations and concepts (Vignola *et al.*, 2010). The preceding paragraphs will explicitly deal with the various perceptions held by indigenous people on what climate variability means, the causes and impact on agricultural activities.

2.6.2 Perception of climate variability

Climate variability is a phenomenon that is perceived differently by different people. People‟s perception may be based on their indigenous knowledge or to some extent, their educational background. Again, it is also important to note that, the perception of people on the varying climate may be regionally biased as different people across different regions may perceive climate variability differently. Myriads of evidence from a number of African countries reveals that large numbers of farmers perceive that the climate has become hotter and the rains less predictable and shorter in duration (Gbetibouo, 2009).

According to the study of Tunde (2011) on farmers‟ perception of climate variability on agriculture in Nigeria, majority of farmers (47.2%) in the region perceived climatic variability as delayed rainfall. In addition, the study alluded that 22.2 percent perceived climate variability as high temperature, 5.6 percent said it is flood, 2.8 percent observed it as unusual rainfall and 22.2 percent perceived it as undefined season. The author therefore concluded that farmers in Nigeria perceived climate variability as increase in temperature and inadequate/ excessive rainfall, flooding and changes in weather pattern. These variations as perceived by the farmers in the country will inform the decision of farmers on the kind of adaptation strategies to implement to help cope with the variations and its effects.

Ogalleh *et al.* (2012) studied local perceptions and responses to climate change and variability in Laikipia in Kenya. According to the study, rainfall was observed to be decreasing while temperature and wind were observed to be on the increase. The author alluded that, farmers did not experience these variations in the 1960‟s, 1970‟s and the 1980‟s but started experiencing these weather and climatic oscillations after the 1980‟s. The perception of the farmers in this region stems from the various observations made by farmers over the decades which showed some anomalies that had never been experienced in the past. A similar study conducted in Zimbabwe by Mudombi (2011) revealed that farmers in Zimbabwe especially, the Murewa district perceive climate variability as increase in drought conditions, heavy precipitation and violent storms which were never experienced in the past decades. The findings show that smallholder farmers in Zimbabwe perceive the changes in the timing of seasons, and changes in characteristics within seasons e.g. extreme events such as droughts, floods and destructive hailstorms becoming more common.

Moreover, Mubaya (2010) avers that most smallholder farmers (80%) in Zambia and Zimbabwe were aware of the changes in climate over the years. The study further avers that, farmers in the two regions perceived climate variability as floods and excessive rainfall coupled with the oscillations in the weather patterns over the years. It is clear from the study that, even though flood and excessive rainfall were perceived by most farmers in Zambia and Zimbabwe as evidence of a changing climate, a section of the farmers in Zambia (10%) and Zimbabwe(18%) forming the minority indicated that they have not seen any changes in the climate.

Kemausuor *et al*. (2011) on farmers‟ perception of climate change in the Ejura Sekyedumasi in Ghana shows that, majority of farmers (82%) perceive climate change as evident through the warming temperature and changes in rainfall timing from 1993 -2006. A greater number of farmers (93%) established the fact that there have been irregular and unpredictable rainfall pattern which has culminated in a reduction in precipitation with the potential to cause drought. The study further recommends that farmers should be given enough education on their farming practices as well as enhancing their adaptive capacities to help them respond positively to the changing climate.

Mengistu (2011) studied farmers‟ perception and knowledge of climate change and their coping strategies in Adiha, Nigeria. The results revealed that, about 75 percent of farmers perceived that the temperature of Adiha had increased in the last two decades. Conversely, 90 percent of the respondents observed changes in rainfall patterns in the last two decades, and 70 percent noticed a decrease in the amount of rainfall. This shows that farmers and for that matter local people in Nigeria are very much familiar with the changing climate through some observations made over the years.

2.6.3 Perception of the causes of climate variability

The cause of climate variability is one of the debatable issues in recent climate discourse. While some people attribute the causes of climate variability to anthropogenic factors, others perceive it to emanate through natural factors. Some schools of thought even move further to attribute the causes to spiritual factors especially, those who are dogmatic in some religious sects. All these perceived causes give a plethora of dimensions of the causes of the phenomenon and the persistent ongoing debate.

The study of Mubaya *et al*. (2012) on farmers perceptions regarding climate change and variability as a threat to livelihoods in Zimbabwe and Zambia showed that, majority of farmers in the study areas perceived the causes of climate variability to natural factors and as a natural phenomenon without any intervention being responsible for the variability. Some of the natural causes that were cited included natural changes in winters, low or high temperatures and changes in wind movement as experienced in the two countries. These show that, most of the farmers in the two countries down played anthropogenic forcings which is widely asserted as one of the major causes of climate variability. However, some farmers in Monze (33%) and Sinazongwe (17%) in Zambia recognised human induced factors such as deforestation as a major cause of climate variability. Also, some farmers in Lupane (45%) and Lower Gweru (27%), in Zimbabwe alluded the causes of climate variability to the wrath of cultural spirits and God who have meted out such punishment on them for some wrong doing. This means that, the level of perception of people on the causes of climate variability has some relationship with the level of one‟s experience and religious inclination to a larger extent.

Similarly, Tunde (2011) on the perception of climate variability on agriculture and food security in Ondo State, Nigeria, reveal that majority of the farmers (50%) attributed the causes of climate variability to natural causes. However, 27.8 percent said it is caused by anthropogenic activities while 22.2 percent alluded the cause of the changing climate to God"s annoyance. The study recommended that local communities should be made to take part in the debate on climate change. When local communities are involved in climate variability discourse, they will be enlightened to appreciate some of the scientific underpinnings of the causes of the phenomenon and the appropriate strategies to adopt to cope with the situation. Again, policy makers will be abreast with the indigenous knowledge available and the need to build on that knowledge to empower the local people to adopt effective adaptive strategies.

Contrarily, Abaje *et al*. (2014) on climate variability and change impact and adaptation in Katsina State, Nigeria, show a different perception as majority of the respondents perceived the causes of the climate variability to be primarily spiritual. According to the study, (83%) of the respondents opined that community disobeying God is one of the major causes of climate variability and change. This therefore adds another dimension to the climate change discourses in the area of the causes of the phenomenon. The study therefore concluded that non-scientific proven causes (community disobeying God) is a major cause of climate variability and change as believed by majority of the respondents.

According to the study of Manyatsi *et al.* (2010) on rural communities" perception of climate variability and change in Swaziland, some causes of climate variability are scientifically proven whiles others are not. The study reveals some of the scientifically proven causes such as industrial pollution, destruction of nature and car gas emissions. On the other hand, some of the causes that were unscientifically proven included breakdown of tradition, communities disobeying God, retributions and supernatural powers. It can clearly be seen from the study that the scientifically proven causes of climate variability were basically anthropogenic forcings while the unscientifically proven causes dwelt on societal and spiritual causes. Therefore, causes resulting from natural factors were de-emphasised as far as this particular study is concerned.

2.6.4 Perception of the effects of climate variability

There are varieties of ways by which people perceive the impact of climate variability. The perception of people basically stems from their observations and experiences of the oscillations in the temperature and rainfall regimes of their respective localities. It is worth noting that the varying climate affects food crop farmers in most parts of sub-Saharan Africa. For instance, there have been myriads of empirical studies on how farmers perceive the level of impact of climate variability on crop production.

According to one study by Abaje *et al.* (2014) on climate variability and change, impacts and adaptation strategies in Katsina state, Nigeria, decline in crop yield was identified by farmers as one of the major impacts of an increase in temperature, high rainfall variability, and high incidence of flood occurrences. The implication of such a reduction in crop yield will cause an increase in the price of food crops in the area. This will have future repercussion on food availability and a threat to food security. As a result of the enormity of the impact, there is the need for stakeholder engagement to help put up appropriate strategies to enable farmers cope with the impact. This will go a long way to prevent hunger as projected by the IPCC in its series of assessment reports and to also help achieve the Millennium Development Goal (MDG) of eradicating hunger.

Similarly, Mubaya *et al*. (2010) aver that the most contributory factors leading to low crop yield as perceived by farmers in most districts in Zambia and Zimbabwe were droughts and most rivers drying up. One principal effect of the low crop yield identified in the two countries (Zambia and Zimbabwe) as indicated by the study during this period was food insecurity which led to hunger. The study therefore concluded that, the reduction in crop yield could have significant impact on the income and livelihoods of farmers which could incapacitate them to take up social responsibilities.

Moreover, the study of Ogalleh *et al.* (2012) on how local people perceive and respond to the variability and changes in climate in Kenya reveal that, smallholder farmers in the country perceived increased incidence of crop diseases and livestock diseases as some of the major impacts of climate variability. Excessive rainfall and drought conditions have the potential to cause a crop failure with serious consequences on food availability and accessibility. Again, the reduction in crop yield and livestock through diseases has the potential to threaten farmers‟ livelihoods and make them more vulnerable to poverty.

2.7 ADAPTATION STRATEGIES TO CLIMATE VARIABILITY RISKS

2.7.1 Introduction

Adaptation is one of the means by which people and farmers in particular adjust in their attempt to cope with the shocks that emanate as a result of the varying climate.

As a result, the issue of sustainability is therefore relevant in dealing with the wide varieties of shocks through short term and long term coping and adaptation strategies respectively. Adaptation has therefore become a necessary condition in climate variability research. Recognising that the responsiveness and adaptation mechanisms act as indicators of whether social systems are becoming more resilient to climate variability impacts (Campos *et al.*, 2014). According to Walker and Salt (2006) adaptation reflects learning, flexibility, the ability to experiment with and adopt new solutions, and the development of generalised responses (individual and collective) for a wide varieties of challenges. The paragraphs that follow will delve into the various adaptation strategies adopted by farmers as well as the factors that influence farmers‟ adaptation strategies and the relevance of such strategies.

2.7.2 Adaptation practices of farmers in Africa

Adaptations in agriculture vary depending on the climatic stimuli, farm types and locations, economic, political as well as institutional conditions (Smit and Skinner, 2002). They include a wide range of forms (managerial, technical and financial), scales (local, regional and global) and actors (farmers, industries and governments) (Reidsma, 2010). Adaptation may also be seen as either planned or autonomous. Planned adaptation focuses at the governmental level with particular reference to changing decision making processes such as providing relevant information and technical assistance. On the other hand, autonomous adaptation focuses at the individual farmer level and involves innovative changes in agricultural practices that may occur by trial-and-error, farmer experience, or by changes in the decision-making environment resulting from planned adaptation (Easterling *et al.,* 2007). According to Smit and Skinner (2002), adaptation options that are available can be grouped into four major categories namely: farm production practices, farm financial management, technological developments and government programs and insurance. These groups of adaptation options have the potential to help improve food production and food insecurity when they are effectively implemented.

The study of Zorom *et al.* (2013) on climate variability and adaptation practices of farmers in the Sahel region shows the adoption of numerous adaptation strategies to cope with drought conditions. Some of the strategies adopted included the diversification to non-farm activities such as the selling of poultry and rearing of ivestock as alternative measures as well as the reduction of food intake. Again, some farmers also engage in the cultivation of dry season irrigated vegetables. RodriguezSolorzano *et al*. (2014) argue that these practices help farmers to distribute climate risks over different economic activities which strengthen their financial capacities to be able to raise their purchasing power. This enable farmers to absorb the shocks of the changing climate and help them to also improve upon their livelihoods.

Hisali *et al.* (2011) studied adaptation to climate change in Uganda using micro level household data to ascertain the varieties of adaptation options employed by farmers in Uganda. According to the study, reducing consumption and utilising past savings were some of the short term strategies employed by farmers. However, the study notes that, though reducing consumption and utilising past savings for example are probable short term strategies, they rather make more farmers vulnerable unlike the long term strategies such as the supply of labour which is more sustainable. However, it is also important to note that, the supply of labour is also subject to the demand for it as well as well-established policies that bolster the capacity to absorb the greater population willing to sell their labour.

Mary and Majule (2009) also studied climate variability and change and adaptation strategies in semi-arid areas of Tanzania using the Participatory Research Approaches (PRA). The study reveals that most farmers in Kamenyanga and Kintinku in Tanzania employ crop diversification as an adaptive strategy through the method of mixed cropping where farmers grow different kinds of crops on the same piece of land. This strategy is normally adopted as a means to spread the risk and expand the opportunities for farm profit such that, farmers will be able to get something from particular crops should some crops fail under the vagaries of the changing climate (Uddin *et al*., 2014)

According to the study report of Bryan *et al.* (2010) to the World Bank on adaptation of smallholder agriculture to climate change in Kenya, farmers employ a plethora of adaptation strategies such as changing crop variety (33%), changing planting dates (20%), and changing crop type (18%). These strategies have the potential to help farmers show resilience in the wake of the shocks of the varying climate. However, the study also showed that a significant number of 19 percent failed to adapt. The implication is that majority of such people become vulnerable than those who adapt. They recommended that, meteorological data or information should be made available to farmers as well as basic education given them to enable them become well informed in order to adjust their planting dates.

The study of Hassan and Nhemachena (2008) on the determinants of African farmers‟ strategies for adapting to climate change in Pretoria using the multinomial econometrics analysis reveals that, some farmers in the region employ agro-chemicals and fertiliser application as a means of adapting to the effects of the changed climate. However, the study noted that the application of agro-chemicals as well as the changes in the type of agro-chemicals as adaptation strategies was determined by accessibility to credit facilities which financially empowered the farmers in employing those strategies. Similarly, Tshiala and Olwoch, (2010) revealed in their study that, farmers ability to increase tomato yield in the Limpopo Province, South Africa, was as a result of some adaptation strategies like the application of agrochemicals they employed. The study of Owombo *et al*. (2014) revealed a variation of adaptation techniques between males and females. For instance while males employed irrigation, the females did not. This was attributed to the skills, cost and energy involved in some of these activities. Generally, majority of females (56.3%) failed to employ adaptation strategies.

Pangapanga *et al.* (2011) in their study of Southern Malawi to unravel strategic adaptation choices towards drought and flood observed that, irrigation farming was one of the major strategies farmers adopted in their attempt to cope with the pressures of the impact. The study further revealed that household characteristics such as education, gender, income and extension were important features that significantly influenced lower land based household choices of adaptation. For instance, according to the study, a household that had education (formal) was able to adapt as compared to those without education. The study therefore recommended that household characteristics of farmers should be properly mainstreamed beforehand for successful adaptation towards drought and floods in Malawi. Similarly, Tshiala and Olwoch (2010) identified irrigation as an effective adaptive strategy that enhances the improvement of tomato yield. On the contrary, the study of Calzadilla *et al.* (2014) in South Africa on the impact and adaptation to climate change shows that irrigation farming though a necessary adaptation practice is not sufficient enough to reduce the impact of the changing climate. However, the study revealed improvements in agricultural productivity as an effective strategy that could help offset the negative impacts of climate change.

Bagamba *et al.* (2012) also conducted a study in Uganda to assess climate change impact and adaptation strategies for smallholder agricultural systems. According to the study, farmers in Uganda resort to several adaptation strategies to curb the changing climate in the short term and long term as well. Changes in production techniques and changes in location were identified as some of the strategies adopted by most farmers in Uganda. Changes in production techniques help farmers to explore new ways of producing crops through appropriate technology to be able to increase production and respond to the needs of consumers. Again, it is important to note that, changing location though may be ideal, but much will also depend on the availability of land and the nature of the land, especially, areas that are not susceptible to flooding.

Antwi-Adjei *et al.* (2013) studied barriers to climate change adaptation in sub-Saharan Africa with evidence from north-eastern Ghana. The study identified migration as an adaptive strategy by farmers. According to the study, at least one person from a household in northern Ghana had migrated to southern Ghana over the period of 2006-2011 as a strategy to cope with the climatic variations in the region. McLeman and Smit (2006) emphasis that migration as an adaptive strategy within a broader set of potential adaptive responses help individuals to minimise their vulnerabilities to the pressures of environmental changes. Most of these migrants sell their labour for money, however, because of accommodation problems most of these people are exploited by landlords. Migrants are therefore forced to exchange their labour for accommodation and that puts them in a subservient position of getting little for their labour. Eventually, the migrants end up compounding the social problems of cities through the pressures on social facilities and sanitation problems.

2.7.3 Factors and barriers of adaptation strategies

Several factors and barriers come together to influence people, especially farmers in their bid to responding to the shocks of the varying climate. According to Eakin *et al*. (2012), the differential capacity of people, as individuals and in communities, to respond and adapt is influenced by a wide set of site-specific environmental, historical, socio-economic, and institutional variables which act conjointly. There are two ways of farmer‟s adaptation to exposure sensitivity, firstly, through new livelihood channels in off-farm/non-farm area and secondly, through adaptive innovation in the crop farming system (Li *et al.*, 2010). For the non-farm adaptation, Li *et al.* (2010) identified the employment policy and migrant worker‟s capability as the two most important factors that influence farmers‟ decision in their quest to cope with the changing climate. Again, they further postulated that farmers‟ experience through "learning by doing" is one of the major farm factors that influence adaptation strategies of farmers in responding to the impact of the varying climate.

The financial status of farmer household is another important factor that influences farmers‟ adaptation. Household pressures always make farmers develop that strong willingness to take adaptive innovation to respond to the risks of climate variability. Therefore, without the available resources and technologies, the implementation of adaptive strategies will become a myth (Li *et al.*, 2010). The study of Campos *et al.* (2014) postulates that community-based governance system has become an additional strong factor that determines the coping strategies of most farmers in global climate variability. The structural arrangement regarding the governance system of a given locality informs the thinking and the way by which farmers develop strategies to cope with the changing climate. Other factors that are also relevant and can influence decision making regarding adaptation strategies in coping with climate variability ranges from behavioral and socio-economic to gender and ecological (Hisali *et al.*, 2011).

According to Below *et al.* (2010), cognitive factors, such as experience, influence farmers‟ processing of the probability of climate events, as well as their ability to apply climate forecasts are important factors that determine farmers‟ adaptation strategies. Several studies such as that of Maddison, (2007) and Deressa *et al.* (2009) have also highlighted the relevance of socio-economic factors such as education, wealth status and availability of resources (such as land, credit and water storage facilities) in adaptation practices of farmers. In addition, Valdivia *et al.* (2002) also recognised the importance of distance to markets, availability of extension advice (information), farm and household size, and tenure status as some of the major factors that also determine farmers‟ ability to adapt to the changing climate.

According to one study by Bryan *et al.* (2013) in Kenya, access to irrigational facility is a major determinant factor that influences farmers‟ strategy of changing crop types to cope with the changing climate. This implies that, farmers would mostly change the type of crops grown when the particular crop of interest requires irrigation. Beside irrigation are factors like having access to social safety nets (food emergency reliefs, food subsidies or other farm supports); access to extension services and availability of climate information. Moreover, the study also revealed that farmers‟ membership in associations had some level of relationship with the kind of adaptation strategies adopted. According to the study, the number of associations to which members of the household belong negatively influences the likelihood of changing crop varieties. All these factors are opportunities farmers have at their disposal in the wake of adapting to the changing climate.

The type of farming system as well as appropriate technology is also a contributory factor that determines farmers‟ practice of adaptation strategies: those involved in mixed crop and livestock farming, as well as those engaged in subsistence farming and appropriate technology wre more likely to adapt to changes in climatic conditions than are farmers in specialised farming systems (Nhemachena and Hassan, 2007).

One of the socio-economic characteristics that determine farmers‟ adaptation strategies is age. It has been found in several studies that age had no influence on a farmer‟s decision to adapt through soil and water management practices (Anley *et al*., 2007). Conversely, the study of Owombo *et al*. (2014) in Ondo State, Nigeria on farmers‟ adaptation to climate change found that age to a larger extent has some level of positive relationship with adaptation practices.

Various studies have shown that gender is an important variable that influences farmers‟ decision on adaptation choices at the farm level. While Female farmers in Ondo State, Nigeria have been found to be less effective in employing adaptation practices as compared to their male counterpart (Owombo *et al*., 2014), Bekele and Drake‟s (2003) study on soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia alluded that, gender has no significant influence on farmers‟ decisions to adapt.

One major barrier that hinders farmers‟ ability to adapt is finance (IPCC, 2001 cited in Mudombi, 2011). Whether farmers‟ economic conditions are expressed in terms of economic assets, capital resources or financial means, they are clearly a determinant of adaptive capacity. The employment of adaptive strategies at the farm level through technological advancement and even local knowledge involves money. However, since poor communities are mostly financially incapacitated, they lack the empowerment to adapt, which keep them in a more vulnerable situation (Mudombi, 2011). It is therefore important that smallholder farmers are given the needed financial empowerment in order that they can adapt to the climate variability (Ngigi, 2009 cited in Mudombi, 2011).

2.8 THEORETICAL UNDERPINNING OF THE STUDY

This section aims at placing this research in a scholarly perspective by describing the theoretical foundation that underpins the study. Indeed, there have been myriads of theories in an attempt to explain food security in the context of climate variability impact and adaptation strategies in developing countries. Among these theories are the modernisation theory and the structuralism which were employed by most developing countries to help sustain food production and to reduce poverty among developing countries through agricultural modernisation and industralisation. The weaknesses of these theories made them inadequate in providing a better explanation for ensuring food security among third world economies. In pursuant to providing a better explanation of how to sustain food production through adaptive mechanisms in response to the impact of climate variability, the Action Theory of Adaptation (ATA) was adopted.

The ATA explains the initiative and exercise of adaptation strategies (actions) by various key actors and stakeholders (farmers and institutions) as a response mechanism to reduce the impact of climate variability (Eisenack and Stecker, 2011). According to the theory, actions in the form of adaptation strategies are employed to cope with climate variability impacts. The IPCC (2014) reiterates the need to reduce and manage the impacts and risks of climate change through adaptation and mitigation. The actions require actors and an intention to unleash the needed actions through the actors. The use of adaptation requires the provision of resources as a means to achieve the intended ends. The ATA is strongly built around some key concepts namely stimuli, exposure unit, operator and receptor.

The stimuli concept refers to the change of biophysical variables (e.g. meteorological variables) which are triggered by climate change (Eisenack and Stecker, 2011). The stimuli therefore cause some changes to biophysical variables such as climate variables (e.g. temperature and rainfall) as a result of the impact of the climatic variations. The stimuli become relevant for adaptation when they are able to influence the exposure units.

The exposure unit refers to the non-human systems that depend on climatic conditions, and are therefore exposed to the stimuli (Eisenack and Stecker, 2011). The exposure unit may be extended to cover social, technical and other systems that may be studied in an adaptation study. It is important to note that the combination of the stimuli and the exposure unit constitute the impact.

Receptors are the actors or systems that are addressed by the purpose of an adaptation. The receptors are the target of the adaptation or the social systems that ultimately exercise the adaptation strategies. The receptors can also be both biophysical entities (e.g. the crops of a famer) and social systems (e.g. the farmer household), depending on the objective of analysis (Eisenack and Stecker, 2011).

Operators are the actors or institutions who wield the power, knowledge and means to exercise or initiate the adaptation strategies (Eisenack and Stecker, 2011). Operators are therefore the organisations, institutions or other social systems that facilitate the adaptation strategies of the receptors. For instance, operators can be public or private institution with the knowledge and means to initiate adaptation. The receptors and the operators are actors who initiate and exercise the needed actions in responding to the impact of climate variability and change. Figure 2.1 provides a diagrammatic presentation of the relationship between climate variability impact and adaptation actions.

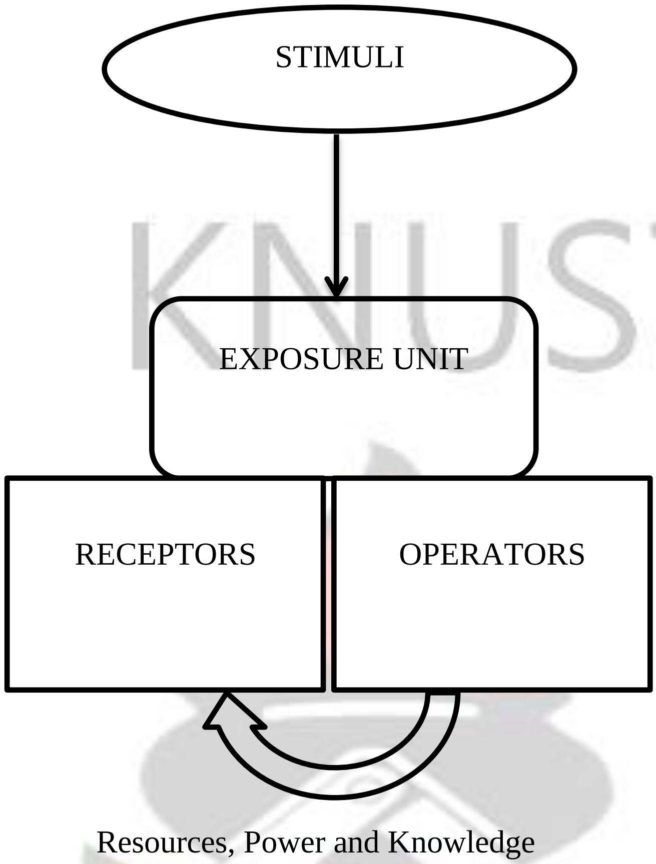


Figure 2.1: Action Theory of Adaptation Framework (ATA) Source:

Adopted from Eisenack and Stecker (2011: 7).

2.8.1 Climate variability impact and adaptation conceptual framework

According to the IPCC AR5, one major factor which remains clear as perhaps being responsible for climatic variations over the years is the emission of greenhouse gases especially carbon dioxide into the atmosphere (IPCC, 2014). The report further mentions human activities, especially deforestation as the leading factor influencing the climatic variations. The net effect of the human activities causes an increase in temperature and changes in the rainfall patterns which are the stimuli which influence the exposure units (crops). Datta (2013) identifies high temperature and rainfall variability as two most important parameters that influence climate variability. Temperature increase (stimulus) could affect tomato production (exposure unit) at every stage of the production process beginning from the planting stage through to the stage of harvesting. High temperature has some direct or indirect relationship with sunshine. A greater sunshine has the propensity to raise atmospheric temperature and this may potentially affect the moisture content of soils. Again, greater sunshine and for that matter high temperatures, may cause a reduction in relative humidity and ultimately increase evapotranspiration.

Rainfall is an important variable that is affected by the changing climate. The changing climate has not affected only the intensity of the rainfall but most importantly, the timing and the amount of rainfall. The reduction in the amount of rainfall (stimulus) could lead to extreme weather conditions such as drought which has the capability to affect tomato production. Drought conditions could have a negative effect on crop yield (exposure unit) (Roudier *et al*., 2011). Again, a reduction in rainfall can cause a reduction in infiltration, runoff, deep percolation and ground water recharge. The over-all effect of these two major environmental variables (stimuli) is the potential effect they have in causing soil moisture deficiency. This could lead to plant water stress and consequently cause a reduction in crop yield (Sarker, 2012).

As a result of the reduction in crop yield due to climate variability, farmers are bedeviled with some level of effects. These effects could be economic as well as social effects (exposure unit). Economically, since most farmers depend on crop production as their source of livelihood, a reduction in crop yield can have significant impact on the livelihoods of farmers (actors) who depend largely on vegetable production, especially tomatoes, and may drag such farmers into poverty. Again, a reduction in crop yield due to climate variability could lead to a reduction in food production which can also cause hunger among people in the locality.

In view of the enormity of the effects of these variables on yield of vegetable crops, farmers therefore take steps to respond to the changing climate through actions of adaptation practices to be able to cope with the situation and maximise production as well. However, the choice of adaptation strategies depends on a wide variety of variables which are considered vital with respect to the availability, accessibility and affordability of particular adaptation methods adopted (Komba and Muchapondwa, 2012). Deressa *et al*. (2009) conclusively emphasised the fact that farmers‟ education, access to extension and credits, climate information, social capital and agro-ecological settings have great influence on their choice of adaptation methods to climate change while financial constraints and lack of information on adaptation strategy also impedes the farmers‟ readiness for proper implementation of adaptation (See Figure 2.2).

2.9 SUMMARY

The literature reviewed unveils the concept of climate variability as a multidimensional concept which defies a single definition. As a result, various scholars have defined the concept from their own point of view. However, one relevant underlining element that permeates the various scholarly definition of the concept is the variation which can either be internal or external.

Climate Variability

(Greenhouse gas emissions)

High Temperature

(Greater sunshine and sun intensity)

Rainfall Deficiency

(Amount, intensity, timing)

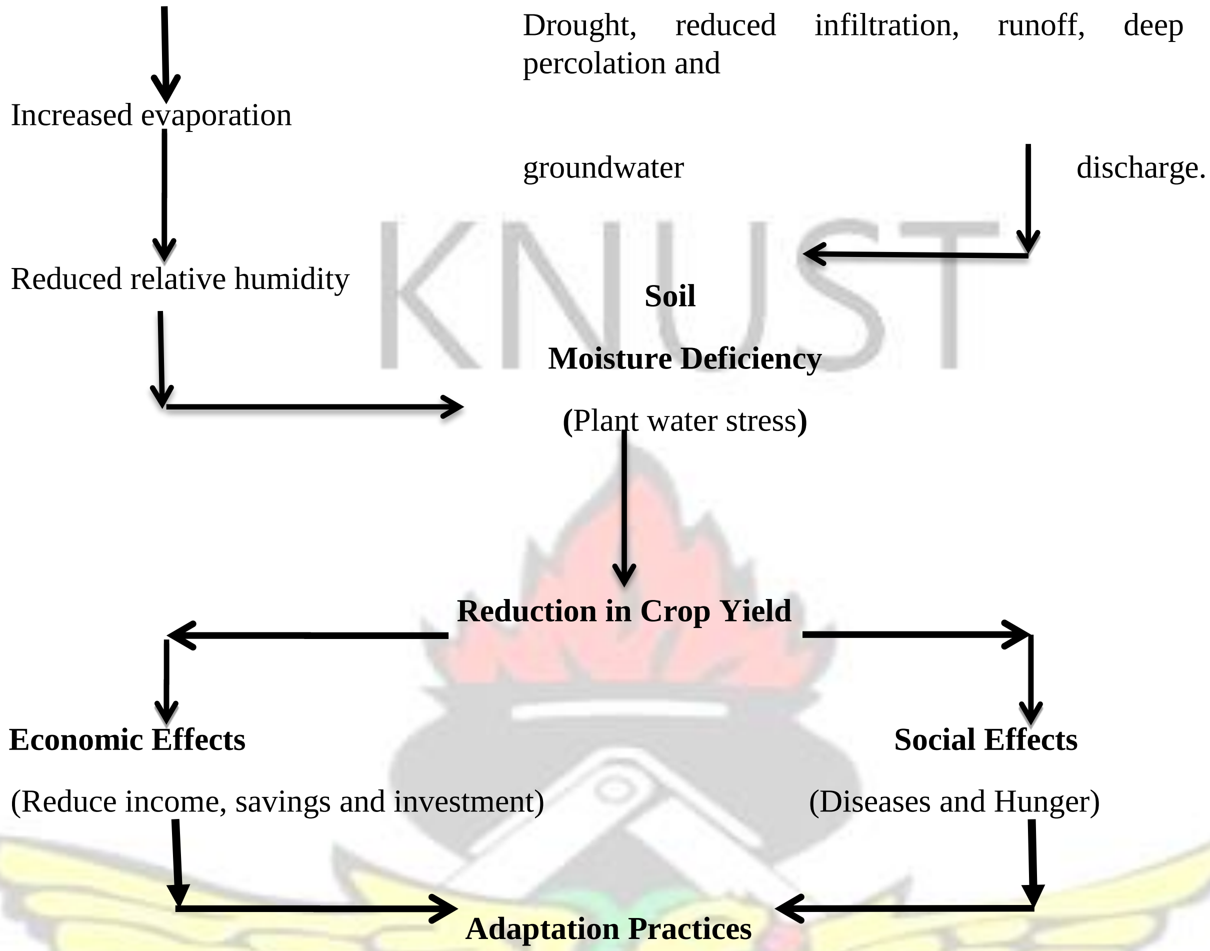


Figure 2.2: Climate variability impact and adaptation framework

Source: Adapted from Food and Agricultural Organisation (2007: 10)

Moreover, the review also revealed an increasing temperature variability trend across the globe with oscillations in the rainfall pattern of most regions. These regional variations in temperature and erratic rainfall pattern experienced among most countries were either attributed to natural causes or anthropogenic forcings. Apart from temperature and rainfall, other variables such as carbon dioxide concentration and sunshine all showed an increasing trend especially in countries in sub-Saharan Africa.

Also glaring in the literature reviewed is the fact that climate variability affects crops in all the dimensions of the food systems i.e. food accessibility, food availability and food utilisation. The review systematically looked at how climate variability affects each of the components of food security and the nexus that exists between climate variability and food production. For instance, it was clear from the review that climate variability affects crop yield which ultimately affect the availability of crops for human consumption.

Furthermore, it is evident from the literature review that farmers have different opinions and perceptions regarding the impact and causes of climate variability. From the review, while some farmers attribute the cause of climate variability to natural means, others perceive anthropogenic causes and spiritual causes as factors that influence the variability of climate. Reduction in crop yield was also perceived by most of the farmers as the major effect of climate variability on crops.

Finally, it has also manifested from the literature review that farmers in their bid to cope with the shocks of climate variability, adopt several on-farm/off-farm adaptation strategies. These adaptation strategies are both short term and long term in character/nature. The use of irrigation schemes, experience and availability of finance were identified as some of the factors that influence farmers‟ adaptation strategies.

CHAPTER THREE

RESEARCH METHODOLOGY AND PROFILE OF THE STUDY AREA

3.1 INTRODUCTION

This chapter focuses on the study methodology and the profile of the study area. The chapter delves into the research approach and design for the quantitative and qualitative studies as well as the types, sources and methods for data collection. It also discusses the sampling procedure, the target population, the sampling technique, sampling design, sampling frame, sample size and data analysis. Again, the study comprehensively illustrates the profile of the study area. Areas covered by the profile encompass the biophysical and socio-demographic characteristic of the Offinso North District. Maps have been used to diagrammatically represent the study area with the selected communities clearly indicated.

The chapter is organised under three major sections. Section 3.2 unveils the research approach and design for the study. Section 3.3 provides a description and diagrammatic representation of the study area in local and national context with emphasis on the climate, vegetation, geology, soil and demographic characteristics. Section 3.4 focuses on the ethical considerations of the study while Section 3.5 summarises the chapter.

3.2 RESEARCH APPROACH

The mixed methods approach was employed for the study. A mixed method is a procedure for collecting, analysing, and “mixing” both quantitative and qualitative research and methods in a single study to understand a research problem (Creswell, 2012). According to Creswell (2010), both quantitative and qualitative data together provides a better understanding of a research problem than either type by itself.

Again, this particular approach is appropriate for this research because using either qualitative or quantitative method would not adequately address the research problem to help the author answer the research questions. The convergent parallel strategy of the mixed method approach was used. This strategy involves the collection of both quantitative and qualitative data concurrently with separate analyses of the two data sets (Creswell and Clark, 2010). The relevance of this strategy is that, both methods (quantitative and qualitative) complemented each other in arriving at the conclusion.

3.2.1 Research design

The cross-sectional design was used for the study. This study design is an observational study which involves selecting a sample of a population at a particular point in time within a shorter period of time without a manipulation of the study environment. The cross-sectional studies therefore aimed at providing a 'snapshot' of the outcome and the characteristics associated with it, at a specific point in time. This design is appropriate for the study as it used the sampled views of the population in order to make generalisation about the target population.

3.2.2 Study population

The target population of the study included all tomato crop farmers in the district. However, the accessible population were tomato farmers in the three selected communities (Akomadan, Nkenkaasu and Afrancho) who were duly registered as at the time of the study. According to the District Directorate of MoFA, the number of tomato farmers as of December, 2014 in the three selected communities was: Akomadan (2966), Afrancho (2754) and Nkenkaasu (1343). Therefore, the total population strength of tomato farmers in the three selected communities summed up to 7063. This number of 7063 tomato farmers formed the accessible population from which the sample was drawn.

3.2.3 Types, sources and methods of data collection

Both quantitative and qualitative data were gathered from the respondents of the communities. Data used for the study were collected from both primary and secondary sources. Primary data were collected from key informants such as tomato farmers, Agricultural Extension Officers and and Field Officers of the Crop Research

Institute while the secondary data were obtained from the District Meteorological Agency and the District Directorate of the Ministry of Food and Agriculture (MoFA) respectively. Farmers were interviewed using structured interview guides which had both closed and open-ended questions. The interview was conducted face-to-face with the respondents. The structured interview was deemed appropriate because most of the respondents in the study communities could not read and write the English Language. In view of that, the questions were read out in their local dialect to facilitate better understanding and to respond to the questions appropriately. The interviews were conducted in the homes and in some cases on the farms of respondents where appropriate. The structured interview guide was categorised under five sections. The first section focused on the farmers" socio-demographic characteristics. The second section dealt with the trend of climate variability. This was followed by questions on the extent of climatic variations on tomato production. The fourth section focused on the views of farmers on the effect of climate variability. Finally, the fifth section explained the adaptation strategies of tomato farmers to climate variability.

Again, in-depth interviews were conducted to elicit responses from the Senior Agricultural Extension Officer, The Technical Officer of Crop Research Institute of Ghana (CSIR-CRI) and the weather station attendant. These individuals were purposively selected as interviewees for the interview with each interview lasting between 45minutes to about 1hour. The interviews were conducted face-to-face with the interviewees. The interviews broadly focused on areas such as perception of climate variability, climate variability trend, effects of climate variability on crop production with emphasis on tomato and institutional support to empowering farmers" adaptive capacities in the wake of the observed climate variability.

Two separate groups were organised for a focus group discussion. The first group comprised male farmers in the district while the second group comprised female farmers. The members from the three communities were brought together at Akumadan and their transport fares were paid to facilitate their movement. A total of eight (8) male tomato farmers were assembled for the Focus Group Discussion (FGD). These were farmers who had vast experience in the tomato business and were therefore in the better position to provide some relevant additional information. The farmers were selected from the various communities under consideration: Akomadan (4), Afrancho (2) and Nkenkaasu (2). Again, eight (8) female tomato farmers were also sampled for the second part of the FGD. The members of the discussion comprised of Akomadan (4), Afrancho (2) and Nkenkaasu (2). In all, 16 tomato farmers from the three communities were involved in the focus group discussion

The FGD for the males and females were conducted on different occasions. For the sake of ethical consideration, the members of the FGDs were personally contacted while explaining the objective of the study clearly to them and to solicit their acceptance. The consent of the members were sought to tape record. Upon their agreement during the FGD session, recorded voices of the members were later transcribed to complement and support the quantitative analysis. To ensure the validity and reliability of the responses of the discussants, their individual responses were repeated by the moderator to affirm the views of the discussants.

Field observations were employed by the researcher to complement the other data collection instruments to get first-hand information on what was happening on the ground regarding their farming activities with particular interest in their adaptation practices. The participant observation technique was employed as the researcher was part of the subjects of the study (farmers) as well as part of the environment of the observed without the farmers knowing the true identity of the researcher as a researcher.

3.2.3.1 Validity and reliability

The questions in the structured interview guide were valid in content since they were theoretically defined and based on the literature on the impact of climate variability and adaptation. The variables were therefore based on the theoretical and empirical reviewed of the literature on the subject of investigation. According to Williams (2003) reliability of the questionnaire is achieved when there is internal consistency regarding the questions asked by the researcher. The internal consistency of the structured interview guide for the study was achieved as respondents were asked relevant questions in more than one way during the face-to-face interview which helped in testing the consistency of the responses.

3.2.4 Sampling procedures

The study followed a logical and coherent sampling procedure that enabled the researcher to collect adequate data that may enable generalisation of the major results.

3.2.5 Sampling technique

Both probability and non-probability sampling techniques were used for the study. Akomadan, Afrancho and Nkenkaasu communities were purposively selected for being the leading producer of tomato in the district. The unit of analysis was individual tomato farmers in the communities. However, the views of key informants such as the Agricultural Extension Officers from MoFA, field officers of the Crop Research Institute of Ghana (CSIR-CRI)) and the Meteorological Service Agency attendant were solicited.

The systematic sampling method was employed to select farmers from each community. The use of this particular sampling method involved three steps. First, the sample interval (k^{th}) was determined by dividing the farming population of the various communities by their respective sample sizes. The second step involved a random sampling of respondents from the various communities. To begin the random process, the first number was picked between 1 and the k^{th} number using the simple random sampling technique through the lottery method. Here, the first number to the k^{th} number were written on pieces of papers and folded in a bowl. Afterwards, a blindfolded person was asked to pick the first number from the bowl which served as the basis for selecting the rest of the respondents using the sample interval. Finally, the k^{th} term was selected successively from the list of tomato farmers until the total number of sample was obtained. This process was repeated in each of the cases of the selected communities. The randomisation of this particular sampling method was to give the respondents equal chances of selection and to also ensure a fair representation of the population in the communities on which generalisations were made. Also, the purposive sampling technique was used to sample heads of institutions that have an interest in climate issues. Table 3.1 shows a tabular representation of how the systematic sampling was done.

Table 3.1: Process of systematic sampling technique

Study Communities	Farming Population	Sample Size	Margin of Error	Sample Interval (k^{th}) Population/ Sample Size	First Number Randomly Selected	Sample Units
Akomadan	2966	159	0.05	$2966/159=19^{th}$	6	6, 25, 44, 63, 82, …
Afrancho	2754	147	0.05	$2754/147=19^{th}$	11	11, 30, 49, 68, 87, …
Nkenkaaso	1343	72	0.05	$1343/72=19^{th}$	3	3, 22, 41, 60, 79 …

Source: Compiled by Author (2015)

3.2.6 Sampling frame

The sampling frame for the study comprised the total population of tomato farmers

(7063) in the three communities who were duly registered with the District Directorate of MoFA. Based on the list of the total number of registered tomato farmers in the district, the sample sizes of the communities were: Akomadan (2966), Afrancho (2754) and Nkenkaasu (1343).

3.2.7 Sample size

A total of 378 tomato farmers formed the sample size for the main survey. Additionally, two separate FGDs were carried out, involving eight (8) males and eight (8) females each. An in-depth interview was also conducted with the Weather station attendant, the Senior Agricultural Extension Officer and the Technical Officer of the

Crops Research Institute of Ghana (CSIR-CRI). The sample size for the quantitative study was determined from the sampling frame using the mathematical model expressed as: n = N / 1+ N (e^2) (Gomez and Jones, 2010). The „n" denotes the sample size; the „N" denotes the sampling frame and the „e" denotes the margin of error. Using 5 percent margin of error with95percent confidence level, the sample size for the study was determined. The equivalent sample size in the study communities were then determined using the principle of proportionality. This is shown in the following tabular representation with the respective percentages of selection (See Table 3.2).

Table 3.2: Study communities and their respective total number of farmers and sample sizes

Study Communities	**No. of Farmers (N)**	**Percentage (%)** [No./Total*100]	**Proportionate Sample** Percentage/100*Total Sample Size
Akomadan	2966	2966/7063*100 =42	42/100*378= 159
Afrancho	2754	2754/7063*100 =39	39/100*378= 147
Nkenkaasu	1343	1343/7063*100 =19	19/100*378= 72
Total:	**7063**	**100**	**378**

2 Focus Group Discussion with key informants	16
The Senior Agric. Extension Officer (MoFA)	1
The Field Technical Officer (CSIR-CRI)	1
The Meteorological Service Agency Attendant	1

Source: MoFA, Offinso North District (2014).

3.2.8 Data processing and analysis

The data for this study were processed and analysed quantitatively and qualitatively. The quantitative data were analysed using both descriptive and inferential statistics with the help of the IBM SPSS Statistics Software version 17 and the Microsoft Excel Software. Analytical tools such as frequency, percentages, Cross-tabulation, Chisquare and trend equations and graphs were used to analyse the quantitative data. Also the three tier analytical framework of transcription, classification and interconnecting were used to analyse the qualitative data.

3.2.8.1 Quantitative analyses

3.2.8.1.1 Bivariate analysis

The descriptive and inferential statistics were analysed using the IBM SPSS Statistics version 17. While the descriptive statistics were represented in the form of tables, graphs, frequencies and percentages, the inferential statistics involved the use of Cross-tabulation and Chi square test of independence. The cross-tabulation was used to establish the linkage between the sex of the farmers‟ and their perception of climate variability effect on tomato production while the Chi-square test for independence analysis was employed to further test the significance of the relationships between the sex of the farmers and their perception of the effects of climate variability on tomato production at 5 percent significance level and 95 percent confidence level.

3.2.8.1.2 Trend analysis

The Microsoft Excel function of linear trend as well as line chart was used to analyse the trend of climate variability in the district. The line chart, trend line, trend equation and the degree of variation within the excel function were used to determine the nature and direction of the trend of the variables under investigation i.e. temperature (maximum and minimum) and annual rainfall. Again, the inter-annual anomalies for the time series data (temperature and rainfall) were calculated using the Microsoft Excel software to assess the year to year variability of the climatic variables over a twenty year period (1994 to 2013) in the district.

3.2.8.1.3 Regression analysis

To measure the effect of key climatic variables (temperature and rainfall) on tomato yield while controlling the influence of other confounding (independent) variables such as irrigation, regular weeding, soil type, use of agrochemicals and tomato variety, the hierarchical multiple regression model was used. Hierarchical multiple regression is used when additional independent variables (confounding variables) are introduced into a model to ascertain the contribution of each of the independent variable (predictors) on the dependent variables (Pallant, 2001). The hierarchical multiple regression values were therefore used to measure changes that occurred in the dependent variable with changes in the independent (predictor) variables. Two stages (blocks) hierarchical regression was employed. The first stage involved the entry of the controlled independent variables (irrigation, regular weeding, soil type, use of agro-chemicals and tomato variety) which explained the variance in crop yield. The second stage involved the entry of the major independent variables of prime interest (temperature and rainfall) to assess their contribution in predicting the dependent variable. The entry of all the sets of variables meant that, the overall model was assessed in terms of its ability in predicting the dependent measure. At each stage of the process, the hierarchical regression identified the key variables and eliminated the weaker ones. The Analysis of Variance (ANOVA) was used to assess the significance of the regression model and the standardized Beta values as well as the P-values were used to evaluate the contribution of each of the predictors (See

Appendix Four). Variables with 0.05 or less probability ($P \leq .05$) were considered significant while variables with more probability ($P \geq .05$) were considered insignificant. The confidence in the multiple regression data for the study was determined using the adjusted co-efficient of determination (Adjusted R^2).

3.2.8.2 Qualitative analysis

3.2.8.2.1 Thematic analysis

The qualitative data from the focus group discussions and the in-depth interviews were analysed thematically using Dey"s (1993) three-step process of transcription, classification and interconnecting. The description involves transcribing data from the in-depth interviews and FGDs into a mass of text. The classification step involves relating the transcribed data into their major themes. Finally, the interconnecting step involves making sense of the themes in relation to the study objectives.

3.3 PROFILE OF THE OFFINSO NORTH DISTRICT

3.3.1 Location and size

The Offinso North District is one of the districts in the Ashanti region of Ghana. The district was formerly part of the Offinso District with Offinso as the capital. In 2008, the Offinso North District was carved from the Offinso District with Akomadan as the District capital. The district lies between longitudes 10 601 W and 10 451 E and latitudes 70 201 N and 60 501 S. The total land area is about 741 kilometres square.

The district shares boundaries in the north with Techiman Municipal Assembly, in the West with the Sunyani Municipal Assembly, in the East with Ejura Sekyeredumasi District Assembly and in the South with the Offinso Municipal Assembly. Again, the district shares boundary with the Nkoranza South District Assembly in the Northeast, the Wenchi District Assembly in the Northwest, the Tano North and South District Assemblies in the Southwest. The South-North Trans-West African Highway traverses the district, thus making it the main gateway to the Ashanti Region from the northern part of the country. It is therefore clear from the above description that, most of the District and Municipal Assemblies bordering the Offinso North District are in the Brong Ahafo Region (Offinso North District Assembly-ONDA, 2013). Figures 3.1 and 3.2 provide a visual impression of the study area in national and local context.

3.3.2 Climate

The Offinso North District lies in the semi-equatorial climatic zone and experiences a double maxima rainfall regime. While the first rainfall season begins from April to June, the second period starts from September to October. The mean annual rainfall is between 1250 mm and 1800 mm (ONDA, 2013). The district experiences a protracted dry season which occurs between the months of November and March.

The protracted dry season affects crop cultivation especially vegetables e.g. tomato in the district, and this drives farmers to adopt some adaptive strategies like irrigation to help improve crop yield. Again, the district experiences bush fires in the dry season and this causes the destruction of the vegetation, and hence contributes to the changing climate. Relative humidity is generally high ranging between 75-80 per cent in the rainy season and 70-72 per cent in the dry season. A maximum temperature of 30^{o}C is experienced between March and April. The mean monthly temperature is about 27^oC (ONDA, 2013). Plate 3.1 shows the weather station at Akomadan, the district capital.

3.3.3 Vegetation

The Offinso North District lies in the moist semi-deciduous forest zone which is intermingled with thick vegetation cover. Nevertheless, there is the vast emergence of Guinea savannah and this is most prevalent in areas such as Afrancho, Akomadan, Nkenkaasu and Nsenoa.

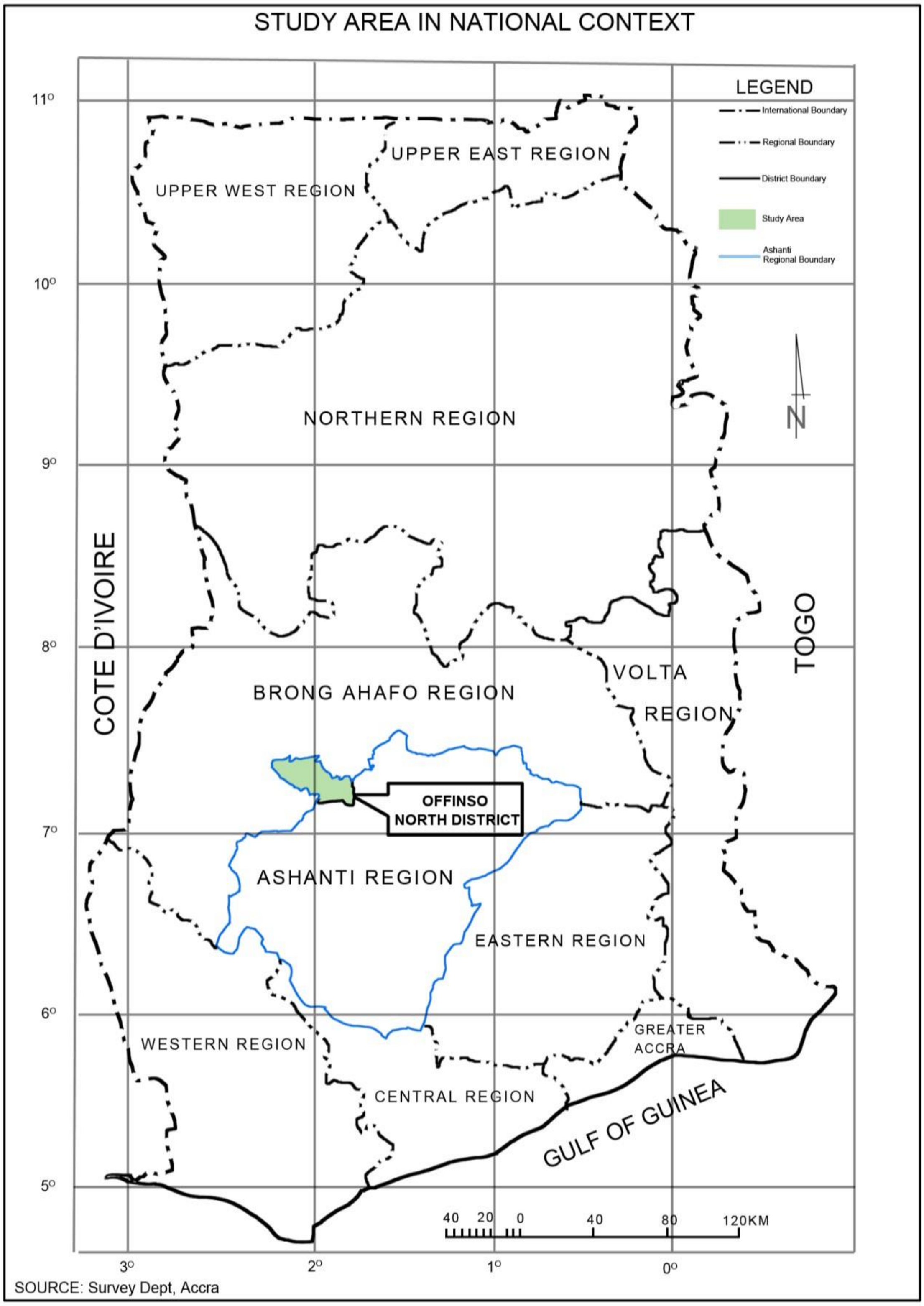
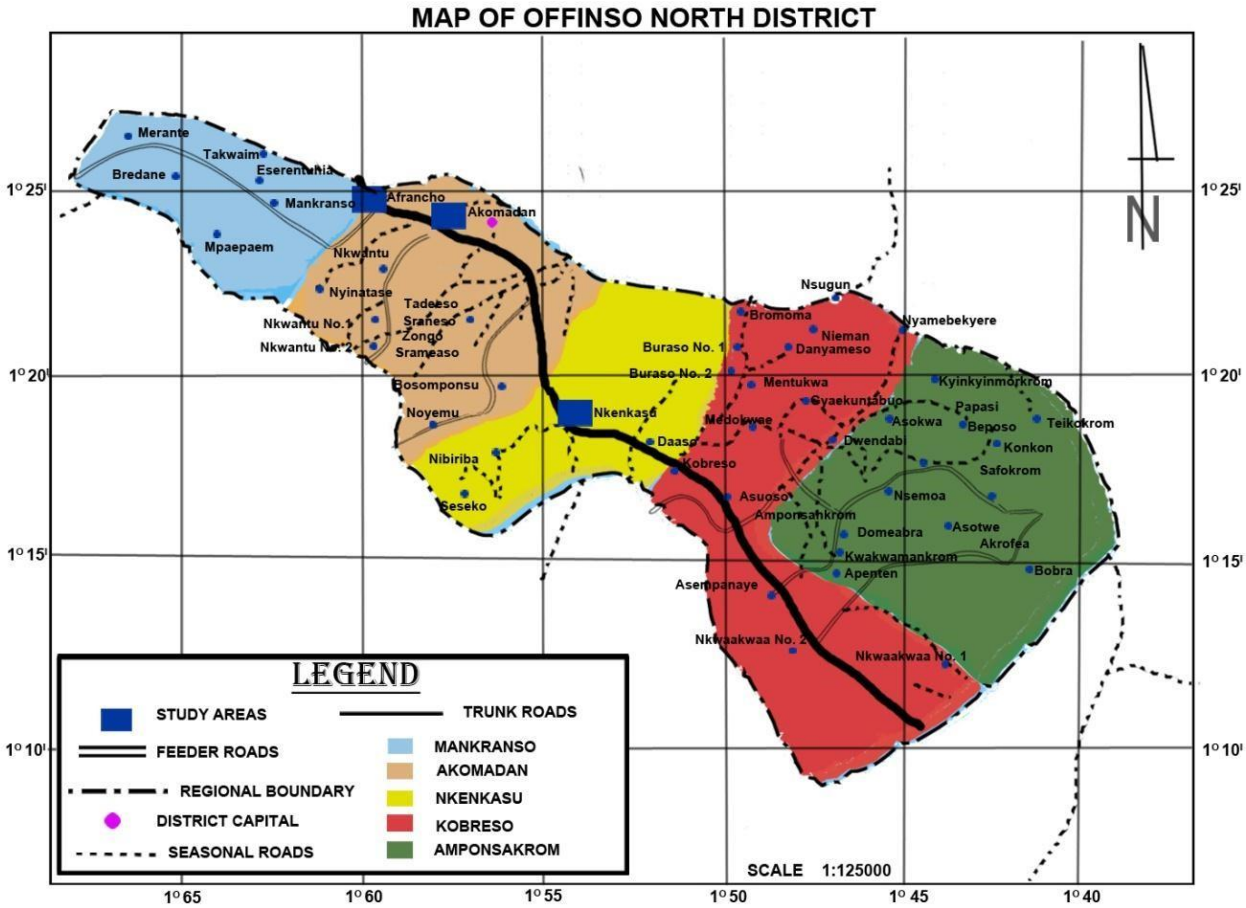


Figure 3.1: Map of Offinso North District in regional and national Context

Source: Survey Department Accra (2014)



SOURCE: OFFINSO NORTH DISTRICT ASSEMBLY

Figure 3.2: Map showing the study communities in the Offinso North District

The four major forest reserves in the district are: the Afram Headwaters Forest Reserve (189.90km^2); the Afrensu-Brohoma Forest Reserve (89.06km^2); the Mankrang Forest Reserve (92.49km^2) and the Opro River Forest Reserve (103.60km^2) (ONDA, 2011). Each forest reserve is composed of trees with economic value such as Odum, Mahogany, Ceiba, Cassia and Wawa. The presence of these forests in the district contributes immensely to the socio-economic development of the district, example timber.

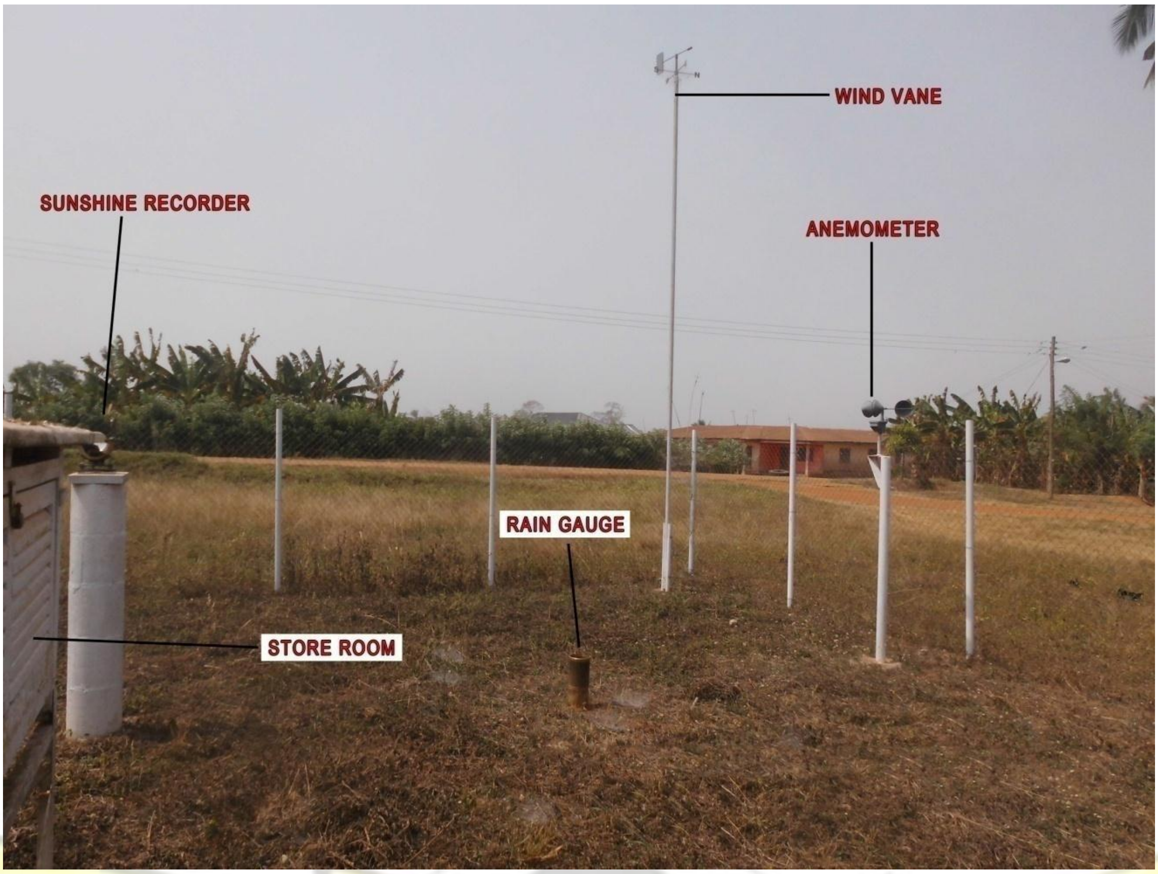


Plate 3.1: The Weather Station at Akomadan Source:

Field data (2014).

However, the activities of timber firms and chainsaw operators in the forest reserves have caused considerable reduction in the number of trees in the area, and have also altered the natural environment considerably. The economic trees have been rapidly depleted. The slash and burn method of farming coupled with the perennial bushfires have also destroyed the ecosystem. It has been estimated that over 90 percent of households in the district depend on wood and charcoal as their main source of energy for cooking (ONDA, 2010). Besides the forest cover, micro-organisms in the soil have also been destroyed thereby rendering the lands quite infertile. This has invariably affected the water cycle. It has also led to the warming of the micro-climate and the altering of the rainfall pattern (ONDA, 2010).

3.3.4 Geology and soil

The district is underlain by two rock formations, namely; the Voltaian and granite rock formations (ONDA, 2010). The Voltaian rocks are found in Afrancho, Kobreso and Nsenoa which are located in the northern, central and eastern parts of the district respectively. The rocks are rich in sandstone, shale, mudstone and limestone. The granite rocks are found in Nyamebekyere in the southeastern corner, Bredane through Mpaepaem in the north-western part to Nkenkaasu and Darso in the central part of the district. The granite rocks form the basis for quarry stones. The granite provides important source of raw materials for constructional purposes (ONDA, 2010).

The soil which is derived from the parent rock in the district is basically loamy and rich in humus. The rich nature of the soil drives most of the people in the district to engage in farming. The soil in the district supports the growth of both food and cash crops. Examples of cash crops grown in the area are oil palm, cocoa, citrus etc. Food crops grown in the area include maize, cassava, plantain and vegetables. Farmers produce these food crops to provide food for their families and sell the remaining for money to cater for the family. Environmental factors such as the changing climate and economic factors like high cost of farm inputs such as agro-chemicals and inadequate credit facilities have been the bane of farmers, and hence a major contributory factor of low productivity in the district.

3.3.5 Relief and drainage

The district has two main relief features, namely; highlands and lowlands. The highlands comprise the mountains and hills while the lowlands are basically plains. The highest point is about 1950 feet above sea level and that is found around Papasisi and Mantukwa in the eastern corridor of the district whilst the lowest point has an elevation of 600 – 1000 feet above sea level and is found around Nkenkaasu and Afrancho (ONDA, 2010).

There are a number of drainage systems in the district. Examples of these drainage systems include rivers, streams and dams. Most of these rivers are drained chiefly by the Pru and Mankran Rivers. Examples of rivers in the district are River Akomadan, River Nkenkaasu, and River Atwetwe with streams such as Kwamasua traversing the district. Most of these rivers have some tributaries. The pattern of drainage systems in this area are of the dendritic type. These rivers and streams are used for domestic purposes with most of the farmers relying on them for their crops. Even though most of these water bodies have fishes in them, the people in the area do not eat them due to some superstitious beliefs. However, it is important to note that most of these rivers and streams dry up during the dry season. The dam at Akomadan is used by most farmers to irrigate their crops especially, on farms closer to the dam (ONDA, 2010).

3.3.6 The interplay between the climate, soil, relief and vegetation

The climate has greater influence on the soil and the vegetation of the study area and its surrounding communities. Major climatic elements such as rainfall and temperature and the nature of the soil have contributed to the cultivation of most of the crops in the area. The cultivation of a wide variety of crops especially vegetables have strengthen farmers‟ financial capacity and an improvement in their standard of living. Also, due to the recent changing climate, farmers in the area have adopted some farming practices to help cope with the situation. Moreover, the copious rainfall during the rainy season may be an influential factor in the vegetation growth in the area. The vegetation provides timber for building and also helps in the formation of rainfall. However, due to human demand for wood for fire and tracts of land for farming, most of the vegetation in the area is threatened through deforestation.

Finally, since the topography of the area is basically lowland, it favours farming activities and the construction of buildings with minimal cost (ONDA, 2010).

3.3.7 Demographic characteristics and the built environment

3.3.7.1 Population size and growth rate

According to the 2010 Population and Housing Census, the population strength of the district was 56,881 with an annual growth rate of 0.24 percent (ONDA, 2010). The population was further projected to be 57,291 at the end of 2013. The spread of the population is concentrated in the principal towns of Akomadan, Nkenkaasu and Afrancho which are urban settlements. The high population numbers are due to the presence of a significant migrant population mostly from Northern Ghana who are farmers. The implication of the high population of the area may increase carbon emissions in the atmosphere which is a major contributor to the changing climate. Again, the increase in population will put pressure on the vegetation and available resources especially land, which may also affect the livelihoods of farmers to a larger extent. The total number of households in the district according to the 2010 PHC was 11,162 (ONDA, 2010).

3.3.7.2 Spatial distribution

The Offinso District has over 95 communities. By the national standard, rural-urban classification of localities is based on whether the population of a settlement is more or less than 5,000 (ONDA, 2010). In the case of a rural community it should be less than 5,000 whilst an urban population should be 5,000 or more. In the case of the Offinso North District only three (3) of the communities can be said to be urban. This includes Akomadan, Nkenkaasu and Afrancho. The vast majority of the communities are therefore rural communities (ONDA, 2010).

3.3.7.3 Population density, sex and dependency ratio

The 2010 Population and Housing Census put the population density at 76.7 people per square kilometer. This figure is lower than the national figure of 103.3 in 2010. This is an indication that there will be available land in the future for agricultural activities especially farming. According to the 2010 Population and Housing Census the male population was 28,300 (49.79%) with the female population being 28,581(50.25%) (ONDA, 2012). The estimated ratio for the male and female population was 1:1.09 indicating that there are more females than males. Again, the 2010 Population and Housing Census revealed that children under 15 years accounted for about 44.4 per cent of the population, economically active population (15-64years) 51.6 percent and the elderly (65 years and above) 4.1 per cent. This implies a low dependency ratio of 0.9 as more people worked to feed the lesser people.

3.3.7.4 Household size and characteristics

The total number of households in the district as of 2014 was 11,164 with an average household size of 5.0. The composition consists of persons from the nuclear and extended families as well as those outside the two mentioned. Heads of households are mainly males. However, there are female household heads too, who are either single or single parent households. Children constitute about 37.3 percent of the average household (ONDA, 2012).

3.3.7.5 Rural-urban contrast

The 2010 Population and Housing Census puts the rural-urban split at 57.8:42.2 as compared to a national average of 56.2:43.8 (ONDA, 2012). However, with about 70 percent of the settlements in the district being rural, the situation poses a problem for the distribution of higher order services and functions in the district (ONDA, 2012).

Services must have the required threshold population before they are provided.

3.3.7.6 Occupational distribution

About 62.3 percent of the population are engaged in agriculture. This reveals that it is the major economic activity followed by commerce which employs about 19.4 percent; service, 14.5 percent and industry, 3.8 percent (ONDA, 2012). This means that, the livelihoods of majority of the population in the study area depends on agriculture. Therefore, there is the need to protect and sustain the livelihoods of farmers through structural and institutional arrangements and interventions. Again, efforts should be put in place to strengthen the adaptive capacities of farmers in order to cope with the changing climate.

3.3.7.7 Water and sanitation

The population with access to safe drinking water is about 23,002 representing about 40.4 percent of the population. Besides, Akomadan, Afrancho and Nkenkaasu which have limited pipe-borne water service, other parts of the district are served by 76 boreholes whilst a much larger part rely on streams for their domestic needs. This situation has serious health implications since these streams are heavily contaminated with agro-chemicals. There is also incidence of water borne diseases. For instance, the number of reported cases of diarrhea in 2010, 2011 and 2012 were 1,634, 3138 and 3,871 respectively (District Health Directorate [DHD], 2012 cited in ONDA, 2013). It is against the background of the demand for increasing access to safe drinking water that the District Water and Sanitation Plan (DWSP) 2010 - 2013 was drawn.

Waste management is poor in the district. The district is characterised by heaped refuse dump sites, unkempt surroundings and inadequate toilet facilities. The district has only one refuse disposal site at Akomadan. Currently Zoom Lion Company Limited is helping in the management of waste collection and disposal along the principal streets in some areas in the district. The district has a total of 1,123 toilets (ONDA, 2013). Out of this, 956 fall under private toilets whilst the public and institutions have 125 and 42 respectively. In terms of the types, VIP toilets constitute about 83.4 percent whilst 82.4 percent are private (ONDA, 2013). The total number of pit latrines is 132 representing about 11.8 percent (ONDA, 2013). Pit Latrines are the dominant facilities in the rural areas. The provision of decent toilet facilities is therefore of paramount concern in the district.

The housing stock in the district is not known as no data has been gathered. However, it is noted that most of the houses are built with landcrete. There are also sandcrete houses which are mostly found in the communities such as Akomadan, Afrancho and Nkenkaasu and some of the communities along the trunk road. These houses are mostly compound houses. There are also a few two-storey buildings located at Akomadan, Afrancho, Nkenkaasu, Kobreso and Asempanaye. However, it is common knowledge that the population outstrips housing. This therefore means that more houses need to be built to meet the housing needs of the people in the district (ONDA, 2012).

3.3.7.8 Economic and livelihood activities

The structure of the district"s economy is made up of agriculture (64.7%), service (14.8%), commerce (17.2%) and industry (3.3%) (ONDA, 2012). Agriculture is the main economic activity in the district. Over 80 percent of the active population in the district are farmers. Out of this figure, the youth constitute about 25 percent. Fishing is done on a limited scale whilst livestock production is basically on free range. Poultry farming is also on a limited scale. Most of the land in the district is put under food crop production each year. Large tracts of fertile lands also remain uncultivated.

The major crops cultivated are maize, plantain, cassava, yam and vegetables especially tomato. Cocoa and cashew production in the district is low and these are the only exportable commodities.

The Akomadan Irrigation Scheme has a potential cultivable area of about 1,000 hectares. However, only 76 hectares has been put under cultivation. Repair works on the dam have been completed by the International Development Association [IDA] and an Indian Company with some support from the District Assembly. It is hoped that it would create employment for the youth during the dry season when it is expected to resume production. There is another irrigation scheme at Asuoso with a cultivable area of about 25 acres. It is a small dugout and water is drawn for irrigation by the use of a water pumping machine. It is used for all year round cultivation of vegetables and rice cultivation by the people of the community.

Cocoa production is not widespread in the district. It is concentrated in areas such as Akrofoa, Tanokwaem, Seseko, Nkenkaasu and Akomadan. Production levels are low, but could be boosted with the necessary interventions. Cocoa farmers receive government support through the Cocoa Pests and Disease Control Programme (CODAPEC) where their farms are sprayed free of charge. Again cocoa fertilisers have been subsidised by the government making it quite affordable to farmers.

About 1200 hectares of land is estimated to be under oil palm production. Oil palm production is still lucrative and receiving quite a good patronage. Lack of processing machinery appears to be the major challenge faced especially by farmers who could be described as medium scale farmers. The ministry could intervene by introducing a facility that could assist the farmers to acquire the palm oil extraction machinery. At the moment, there is no direct support for oil palm farmers in the district. However, farmers regularly receive extension advice from the Directorate. About 376 hectares of land is estimated to be under citrus production in the district. Fruiting in the inland savannah is becoming a problem so farmers are being advised to go into oil palm production.

About 800 hectares is estimated to be under cashew production in the district. The greater percentage of the cashew production is concentrated in the Nsenoa area. Technoserve and Adventist Development Relief Agency (ADRA), both NGOs, were very instrumental in promoting the production and marketing of the cashew. At the moment there is no direct involvement by any NGO in the cashew production in the district and some farmers have abandoned their farms. Area under production used to be around 1200 hectares some five (5) years ago (ONDA, 2010).

There are about three (3) table milling businesses in the district (2 in Akomadan, 1 in Nkenkaasu). There used to be two (2) large saw mill companies operating at Nkenkaasu, but they have folded up as a result of the exhaustion of their concessions. Agro-processing in the district is in the areas of gari –processing, palm oil and palm kennel oil extraction. Gari-processing is carried out in communities such Dwenedabi, Mantukwa and Brohoma and Tanokwaem.

The people of Dwenedabi have been assisted by the United Nation Development Programme (UNDP)/ A2000N to procure a gari-processing plant. This has enabled them step-up production to raise their income levels as well as create employment. Tie and dye production is done at Akomadan. There are a number of tailors and seamstresses in the district. There are a few people who are engaged in the sale of smocks and Kente. Pito brewing is also done at Akomadan, Afrancho, Nkenkaasu and the Nsenoa area. Distilling of akpeteshie (locally distilled hard liquor) is carried out around Afrancho, Tanokwaem and Nkenkaasu. These are owned by individuals. They meet the demand in and outside the district. Sandwinning is carried out in communities such as Akomadan and Darso. As an infant district it is carried out on a small scale. There are a few individuals who are into soap making, but these are rather on a small scale. Mushroom production has been carried out by a group at Afrancho.

They were supported by the UNDP in pursuance of the Millennium Development Goals. However, the group has not been able to advance the project because the support was woefully inadequate. Snail production has also been supported by the UNDP. Snail production is one of the subproject activities undertaken by the group at Afrancho. This subproject has also not been productive. Grasscutter rearing forms part of the UNDP Project at Afrancho. The project has not been lucrative, because the mortality rate of the animals has been high. This is because the people do not understand grasscutter culture. Besides, the concept of group ownership and management of projects of this kind have not been successful. This is because the whole exercise of fending for the animals is left in the hands of one person most of the time (ONDA, 2012).

3.4 ETHICAL CONSIDERATION

Since human beings are placed at the center of the study, the issue of ethics is very paramount. This is due to the fact that, in as much as the researcher intends soliciting views and ideas from respondents to build new knowledge in the area of study, the rights of the respondents must be taken into consideration. As a result, efforts were put in place to ensure that the rights of the respondents were not trampled upon. The study therefore acknowledged the rights of the respondents and made sure that such rights were respected at all instances. Ethical considerations of the study were upheld as the researcher‟s student identification card was issued to the tomato farmers and institutions in the district to get their consent and to authenticate his identity and the need for them to assist in providing credible information for the study.

Also, respondents‟ anonymity was assured during the data collection period. The researcher made sure that the data collected from the farmers and the various institutions were confidentially treated. Voices recorded from the focus group discussion and the interviews were played back to the hearing of the discussants at the end of the discussion. The researcher conducted the interviews and held discussions with the respondents at a time that were most convenient to all of them.

3.5 SUMMARY

This Chapter delved into the methodological underpinnings of the study as well as the profile of the study area. The research approach and design for the study was comprehensibly expounded. Specifically, the study employed the mixed methodological approach and the cross-sectional study design for the research. The study also employed primary and secondary as well as secondary sources of information. Structured interview guides were used to collect quantitative data while in-depth interviews and focus group discussions were used to collect qualitative data. These instruments were supported with the use of field observations to get first-hand information on the issues under investigation. The systematic sampling techniques were drawn from the current master list of tomato farmers in the district to arrive at a sample size of 378. The analytical framework for the study included the use of bivariate analysis, trend analysis, gross margin analysis and thematic analysis.

The study also gave a vivid description of the study area with appropriate maps in local and national extent. Some of the relevant issues focused on the climate and vegetation of the study area. It was quite clear that the protracted dry season adversely affected agriculture in the district. The soil structure and type as well as the geological composition of the area were also looked into. Some of the relief and drainage systems in the area were identified with emphasis on their relevance to the socioeconomic development of the area. Some economic and livelihood activities of the people in the area were also explained. Finally, the chapter disclosed and clarified some of the ethical considerations that were relevant in the entire research process.

CHAPTER FOUR TREND ANALYSES OF CLIMATE VARIABILITY AND ITS EFFECTS ON

TOMATO CROP PRODUCTION

4.1 INTRODUCTION

This chapter focuses on the analysis of climate variability trend as well as the effect of the climatic variations on tomato production in the Offinso North District of the Ashanti Region of Ghana. The analyses encapsulate both quantitative and qualitative data. Secondary data (climate and tomato production data) covering a period of over 20 years (1994-2013) were employed for the study. The climate data was used for the trend analysis while a combination of the climate data and the tomato crop production data were concurrently used to analyse the effects of climate variability. The variables used for the trend analysis were temperature and rainfall. In-depth interviews and focus group discussions were used to gather qualitative data from the respondents. Statistical tools of the IBM SPSS Statistics version 17 and Microsoft Excel software were used for the quantitative analyses while thematic analysis was employed for the qualitative analyses.

The chapter is divided into two major sections. Section 4.2 extensively examines the trend of temperature variability (maximum and minimum) and the rainfall variability in the Offinso North district over the last two decades (1994-2013). It then links up with section 4.3 which expounds the effects of climate variability on tomato production. Specifically, the section teases out the effect each variable, temperature and rainfall, has on tomato production.

4.2 TREND ANALYSES OF CLIMATIC VARIABLES

In determining trend, the climatic variables (temperature and rainfall) were subjected to trend analyses. The Microsoft excel function of trend was therefore employed to show the trend of the climatic variables under consideration with the trend line indicating the nature and direction of the trend. It is quite evident from the trend analyses that, both the minimum and the maximum temperatures have increased over the past two decades with rainfall showing a relatively marginal increasing trend (See Figures 4.1, to 4.6

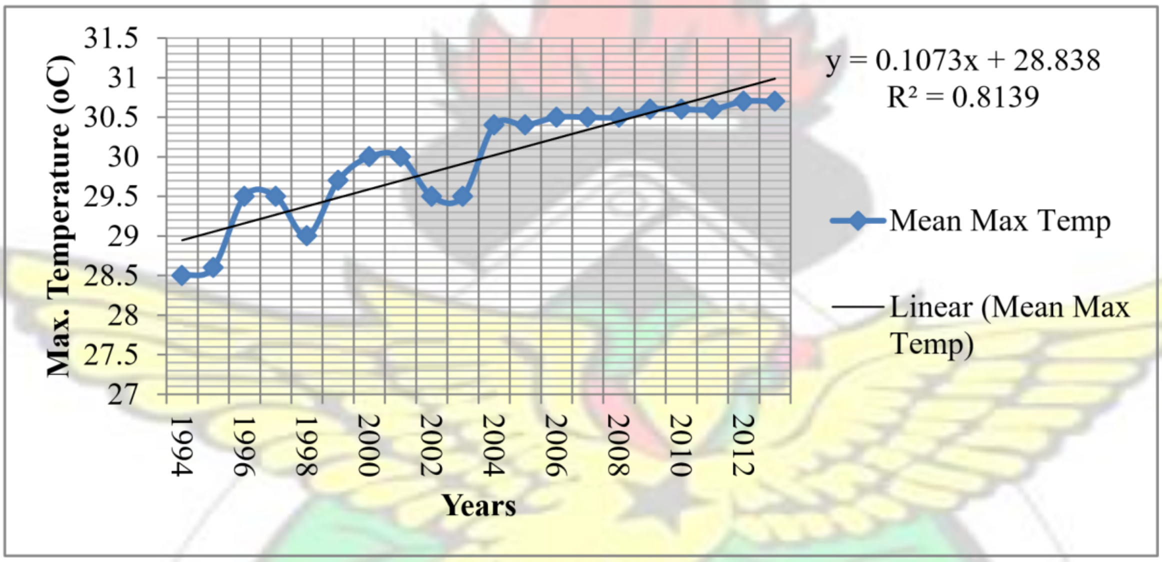


Figure 4.1: Maximum temperature trend in the Offinso North District (19942013)

Source: Field data (2014)

From Figure 4.1, it is obvious that the maximum temperature has varied over the past twenty years (1994-2013) in the Offinso North District. Maximum temperature in the district mostly oscillated and increased sharply, especially within the first decade (1994-2003) as compared to the second decade (2004-2013). From the graph, maximum temperature increased sharply from 1994 to 1996 and thereafter fell to

1998. Again, there was a sharp increase in maximum temperature from 1998 to 2000 before falling to 2002 with 2003 remaining constant. However, during the second decade, maximum temperature sharply increased from 2003 to 2004 and afterwards experienced a relatively general steady increase to 2013. It is observed from the time series data that 2012 and 2013 recorded the highest maximum temperature of 30.7 ^{0}C. The trend equation and the trend line of the mean maximum temperature generally shows an increasing trend (0.1073x) which means that the average maximum temperature over the years (19 94-2013) has been increasing. The degree of variation (R^2 =0.8139) shows that the variability in maximum temperature in the area is approximately 1 percent. The inter-annual climatic variables in the Offinso North District from 1994 – 2013 was also examined (See Table 4.1).

Table 4.1: Inter-annual climatic variations and anomalies

Year	**Mean Maximum Temperature (^{0}C)**	**Anomalies**	**Mean Minimum Temperature (^{0}C)**	**Anomalies**	**Annual Rainfall (mm)**	**Anomalies**
1994	28.50	-1.47	19.50	-0.51	1062.40	-58.96
1995	28.60	-1.37	19.50	-0.50	1372.60	251.24
1996	29.50	-0.47	19.50	-0.50	1178.30	56.94
1997	29.50	-0.47	19.60	-0.41	1079.70	-41.66
1998	29.00	-0.97	20.00	-0.01	1017.90	-103.46
1999	29.70	-0.27	20.00	-0.01	1334.30	212.94
2000	30.00	0.03	20.00	-0.01	1003.00	-118.36
2001	30.00	0.03	20.10	0.09	990.80	-130.56
2002	29.50	-0.47	20.10	0.09	1332.30	210.94
2003	29.50	-0.47	20.10	0.09	1464.20	342.84
2004	30.40	0.43	20.20	0.19	1069.40	-51.96
2005	30.40	0.43	20.10	0.09	1230.30	108.94
2006	30.50	0.53	20.10	0.09	1456.70	335.34
2007	30.50	0.53	20.10	0.09	1100.00	-21.36
2008	30.50	0.53	20.10	0.09	1039.90	-81.46
2009	30.60	0.63	20.20	0.19	1157.20	35.84
2010	30.60	0.63	20.20	0.19	1239.50	118.14
2011	30.60	0.63	20.30	0.29	1088.20	-33.16
2012	30.70	0.73	20.30	0.29	1190.50	69.14
2013	30.70	0.73	20.20	0.19	1275.40	154.04

Source: Akomadan Weather Station (2014)

From Table 4.1, the estimated anomalies of the inter-annual climatic variations show that the amounts of maximum temperature varied from year to year. It is evident from the inter-annual variability graph that there are anomalies in the maximum temperature as observed in the time series data with a greater number of the mean values being positive. These are indications that the district is becoming warmer (See figure 4.2).

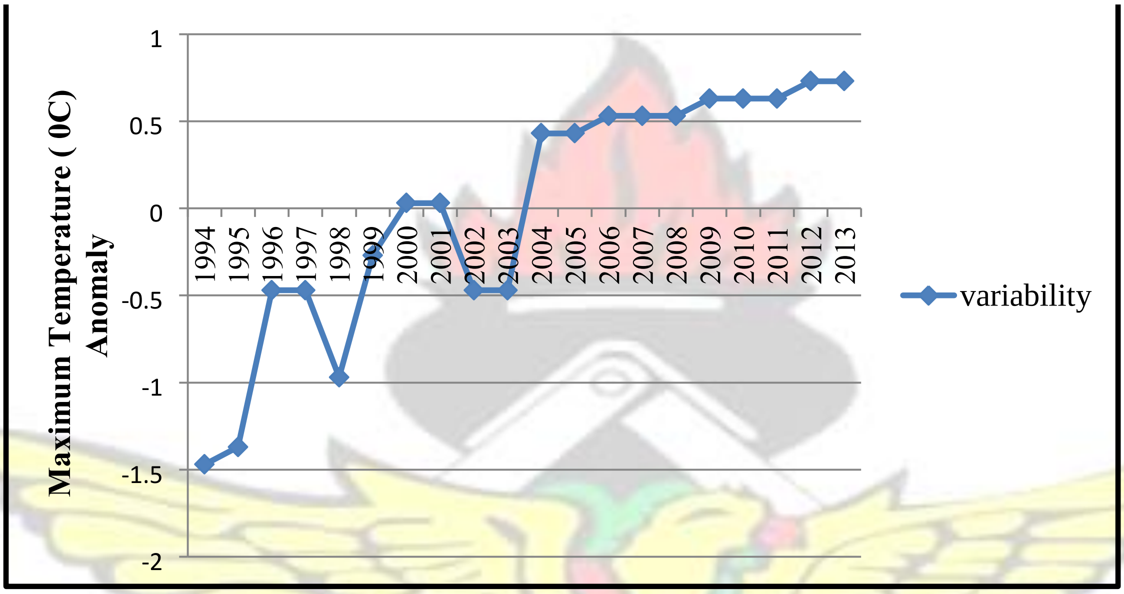


Figure 4.2: Inter-annual maximum temperature anomaly (1994-2013)

Source: Field data (2014)

This is consistent with the study of Hansen *et al.*, (2012) who assert that more warming conditions would be experienced in the 21st century than the preceding decades. Similarly, majority of the farmers during the focus group discussion also acknowledged the increasing trend in temperature over the years. A female discussant in one of the focus group discussions had this to say:

> "*The warming condition of this area keeps increasing year by year. This is making it difficult for us to even sleep in our rooms. If it happens so, some vegetable crops that do not need*

excessive heat are negatively affected" (Focus Group Discussion, 2014).

The perceptions of the farmers were therefore consistent with the climatological data which showed an increasing temperature trend over the past two decades. The reason for the rise or increase in maximum temperature in the district may be partly due to the extent of bad farming practices (e.g. slash and burn) coupled with deforestation that characterises farming activities in the area. The reality about the causes of the increasing temperature trend in the district was reinforced by the assertion made by one of the meteorological attendants who retorted that:

"*The result of deforestation in this area is the high temperature we are experiencing these days. If we keep cutting down trees, the temperature will increase more than what we are experiencing today*" (In-depth interview, 2014).

The implication for the rise in temperature in the district is the fact that, this will increase the rate of evaporation and cause a reduction in soil moisture. When evaporation increases, the result is that the amount of soil moisture lost through vaporization will also increase thereby leaving little or no moisture to support plant growth. In effect, a crop such as tomato which needs some considerable amount of water to grow will be affected. This supports the part of the conceptual framework of the study which looks at the linkage between high temperature and crop yield (see figure 2.2). This anomaly could potentially lead to a reduction in tomato yield in the district. Figure 4.3 portrays the minimum temperature trend in the district over the period, 1994 to 2013. From Figure 4.2, it is also apparent that the minimum temperature shows some variations over the past 20 years (1994-2013) in the Offinso North District.

The graph shows a very sharp increase in minimum temperature from 1994 to 1997. There was a slight decline in 1998 before showing some level of increase between 1999 and 2000.

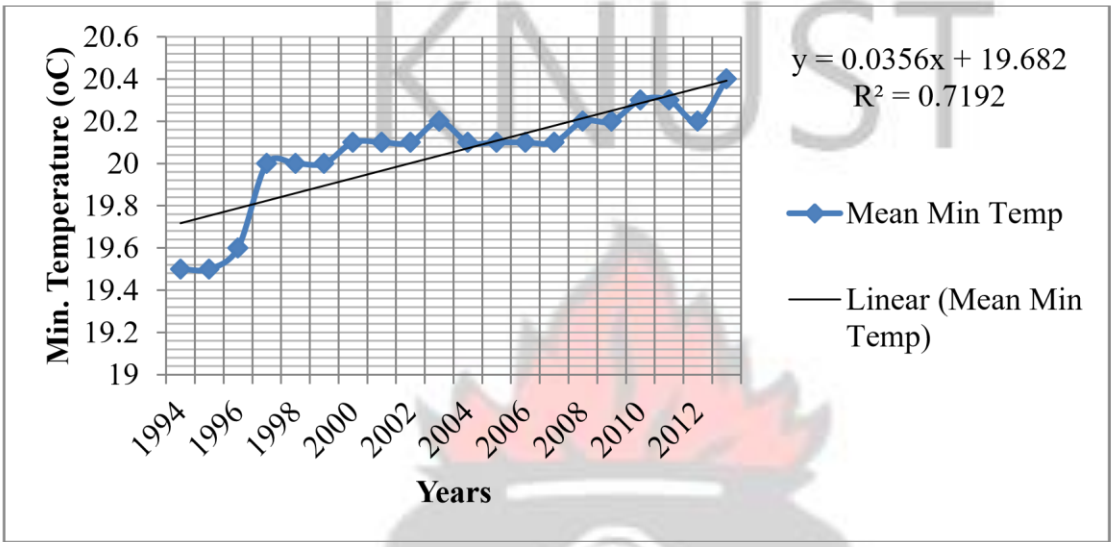


Figure 4.3: Minimum temperature trend in the Offinso North District (19942013)

Source: Field data (2014)

The graph also shows a sharp increase in the minimum temperature from 2002 to 2003 and thereafter fell in 2004. Afterwards, it remained constant between the periods of 2004 and 2007 before assuming some oscillations up to 2011. The minimum temperature fell from 2011 to 2012 and later increased sharply to 2013. The highest minimum temperature (20.4^{0}C) was recorded in 2013. The trend equation and the trend line of the mean minimum temperature generally shows an increasing trend (0.0356x) which means that the average minimum temperature over the years (19932013) has been rising. The degree of variation (R^2 =0.7192) shows that the variability in minimum temperature in the area is approximately 1 percent. Once again, the first decade indicated a sharp increase in temperature as compared to the second decade which showed some slight increases. The estimated anomalies of the inter-annual minimum temperature variations showed the amount of minimum temperatures that have varied from year to year (See Figure 4.4). It is evident from the inter-annual variability graph that there are anomalies in the minimum temperature as observed in the time series data with most of the mean values being positive. This indicates that there is an overall variability in the minimum temperatures in the district.

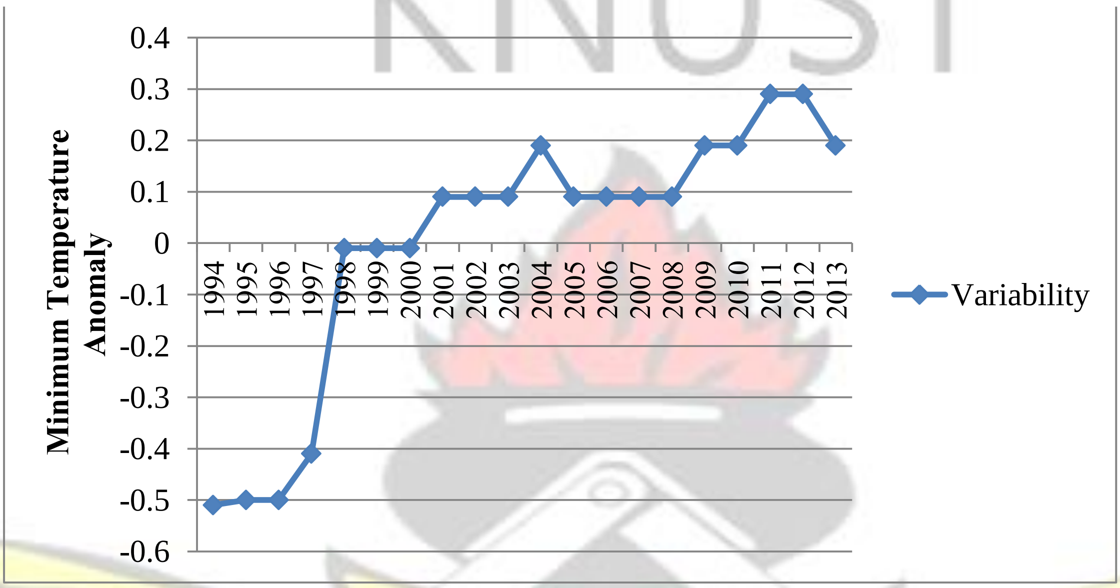


Figure 4.4: Inter-annual minimum temperature anomaly (1994-2013)

Source: Field data (2014)

The implication of an increase in the minimum temperature to crops in general is that, it will affect photosynthetic activities of crops which may in the long run affect the yield of crops, especially tomato which according to Ghartey *et al.* (2012) needs a minimum amount of temperature of about 15 ^{0}C to 20^{0}C for survival. Figure 4.5 gives a detailed account of the rainfall variability trend in the Offinso North District. The annual rainfall amount portrays an increasing trend, notwithstanding the increase in temperature over the periods under consideration. From the graph, annual rainfall increased from 1994 to1995 before declining sharply from 1995 to 1998. There was an increase in annual rainfall again from 1998 to 1999 and fell again from 1999 to 2000. It increased again from 2000 to 2003 and fell in 2004.

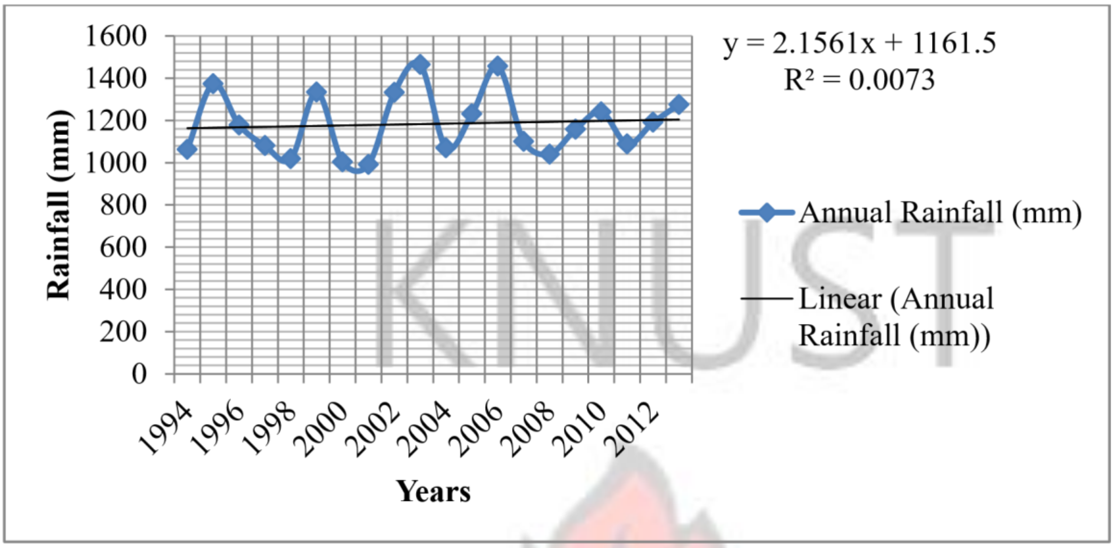


Figure 4.5: Annual rainfall trend in the Offinso North District (1994-2013)

Source: Field data (2014)

It is also clear from the graph that rainfall increased from 2004 to 2006 and later fell sharply in 2008. These variations did not end as annual rainfall amount increased again from 2008 to 2010 and fell again in 2011 before assuming an increasing posture from 2011 to 2013. It is obvious from the graph that rainfall indeed experienced a number of variations over the period under consideration (1994-2013) with the highest rainfall (1464.2 mm) occurring in 2003. The trend equation and the trend line of the annual rainfall shows a gradual increasing trend (2.1561x) which means that the annual rainfall pattern over the years (1994-2013) has been increasing at a steady rate. This means that even though rainfall seems to be increasing over the periods, the trend of increase is generally gradual. The degree of variation (R^2 =0.0073) shows that the variability in annual rainfall in the area is less than 1 percent. The estimated anomaly of the inter-annual rainfall variation shows the amount of rainfall that has varied from year to year (See Figure 4.6). It is evident from the trend anomalies that rainfall as observed in recent years recorded a relatively higher anomaly as compared to the earlier years which showed positive mean values.

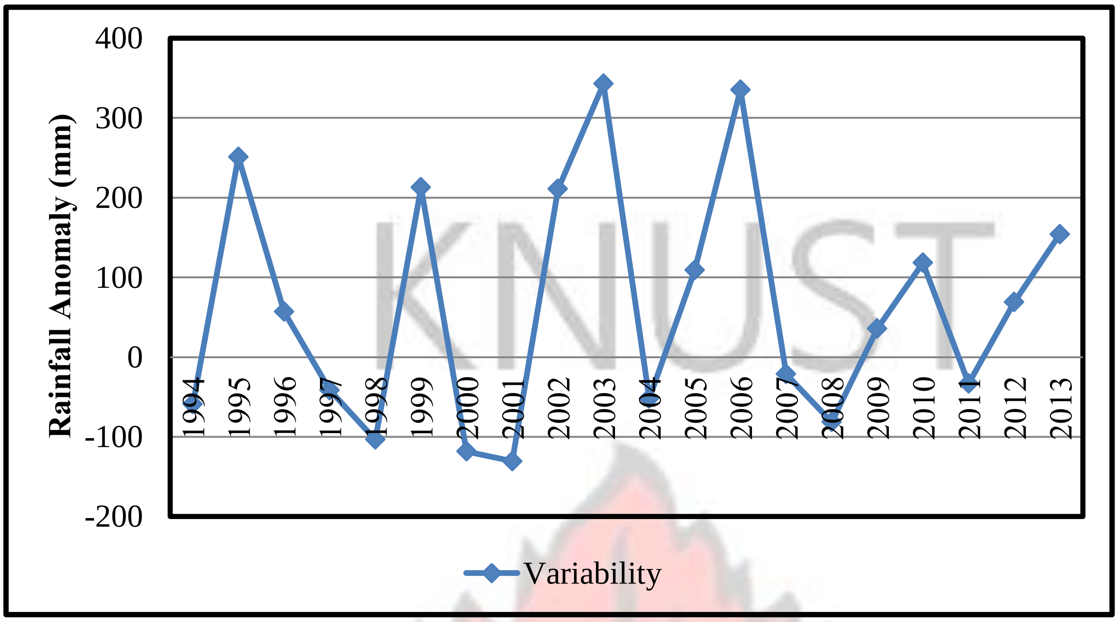


Figure 4.6: Inter-annual rainfall anomaly (1994-2013)

Source: Field data (2014)

This clearly gives an indication of an increase in rainfall in the district. The implication of the inter-annual rainfall analysis shows that the increase in rainfall in the district has the potential to affect tomato crops which do not need copious rainfall, especially during the fruit development and ripe stages. It was also observed that the rainfall peaks in June and October due to the bimodal nature of the rainy season in the district. The peak of the major season was in June while that of the minor season was in October. However, there was uneven distribution of rainfall in the months with the pattern being unreliable over the years. This potentially could have affected most tomato farmers in the district who needed the rains after planting.

This observation contradicts the work of McSweeney *et al.* (2008) whose study revealed a general decreasing rainfall trend of 2.4 percent per decade across Ghana between the periods of 1960 and 2006. However, it was observed during the focus group discussion that, even though the onset of the rainy season delays in the district, the amount of rainfall has increased.

A male discussant of the focus group discussion retorted that:

> *"It doesn"t normally rain but when it does, it comes heavily which mostly destroy our tomatoes. Since most of us depend on the tomatoes for our livelihoods, a reduction in yield affects us a lot especially in taking up social responsibilities like sending our children to school*" (Focus group discussion, 2014).

The general increase in annual rainfall may be due to the fact that, some years recorded very high rainfall which might have generally influenced the overall trend. For instance, from the graph the annual rainfall recordings in the area showed the following figures; 1995 (1372.6mm), 1999 (1334.3mm), 2003 (1464.2mm) and 2006 (1456.7mm). This means that even though annual rainfall increased over the period, the rate of increase was gradual. The high recordings of rainfall in some periods of the years may be detrimental to crop production especially tomato which does not need excessive rainfall at the ripening stage. It is also important to note that the high amount of rainfall in the district as observed by the study may be due to the high temperature recordings which potentially increased evapotranspiration rates. High temperatures will reduce the amount of moisture in the soil which may have adverse effects on crops. Again, the loss of soil moisture through evaporation may have necessitated the introduction of irrigation by some farmers to increase the moisture content in soils to support crop growth.

4.3 EFFECTS OF CLIMATE VARIABILITY ON TOMATO PRODUCTION

This section explores the effects of climate variability on tomato production. In order to control the effect of some confounding variables (i.e. soil type, irrigation, application of agrochemicals, regular weeding and tomato variety) the hierarchical multiple regression was used to explore the relationship between the climate variables and tomato production data. The purpose for this particular analysis was to ascertain the effect of the independent variables in predicting the outcome of the dependent variable. It is clearly evident from the regression analysis that, temperature has a significant relationship with tomato yield while controlling the confounding variables. Again, the result indicates a significant relationship between rainfall amount and tomato yield holding other factors constant. Table 4.2 shows the hierarchical multiple regression analysis of the independent variables in predicting the behavior of the dependent variable.

Table 4.2: Multiple regression factors for independent variables.

Variable	**Beta Coefficients**	**Sig. P-value**	**Adjusted R^2**
Irrigation	.28	.07	.631
Tomato variety	.04	.82	
Regular weeding	.09	.61	
Rainfall	-.27	.00	
Temperature	-.79	.00	

Dependent Variable: Tomato yield

Source: Field data (2014)

To achieve the second objective of assessing the effects of climate variables (temperature and rainfall) on tomato production in the Offinso North District, hierarchical multiple regression was performed to investigate the ability of the two climate variables (temperature and rainfall) to predict the yield of tomato after controlling for confounding variables such as soil type, application of agro-chemicals, irrigation, regular weeding and the variety of tomato.

Prior to conducting the hierarchical multiple regression, preliminary analyses were conducted to ensure there has been no violation of the assumptions underpinning regression analyses. The residual and scatter plots indicated that the assumptions of normality, linearity, homoscedasticity and multicollinearity were all satisfied (Pallant, 2001). The collinearity statistics (Tolerance and Variance Inflation Factor-VIF) were all within the accepted limits. From the analysis the tests for multicollinearity indicated that a low level of multicollinearity was present (tolerance = .993, .741, .619, .572 and .803 for irrigation, tomato variety, regular weeding, rainfall and temperature).

A two stage hierarchical multiple regression was conducted with tomato yield as the dependent variable. Soil type, application of agro-chemicals, irrigation, regular weeding and tomato variety were entered at stage one of the regression explaining 23.0 percent (.23 x 100) of the variance in crop yield. This means that the "control variables" part of the model alone predicted 23 percent of the tomato yield. After entry of the temperature and rainfall at stage two, the total variance explained by the model as a whole was 73.0 percent (.73 x 100), $F(5, 14) = 7.5$, $P = .05$. This means that by adding temperature and rainfall to the model, the variables accounted for a significant 50 percent variance in tomato yield, after controlling for soil type, application of agro-chemicals, irrigation, regular weeding and tomato variety, R Squared change = .50, F Change $(2, 14) = 12.90$, $P = .05$. This means that when all the independent variables are considered, temperature and rainfall predicted 50 percent of the tomato yield. Generally, it is evident that irrigation, tomato variety, regular weeding, temperature and rainfall predicted 63.1 percent of low tomato yield considering the adjusted coefficient of determination (Adjusted R^2) which is .631. This implies that some other factors or variables such as pests and diseases can also influence low tomato yield.

In the final model where the predictive power of all the independent variables were assessed, only temperature and rainfall were statistically significant with temperature showing a higher beta value (beta = -.79, $P < .05$) than that of rainfall (beta= -.27, P<

.05). This means that temperature significantly affects tomato yield, especially when it is above its optimum which is between 21^{o}C and 28^{o}C (Ghartey *et al*., 2012). This therefore supports the study of Kalibbala (2011) who asserted that high diurnal temperatures above 27^{o}C are likely to induce pollen sterility of tomato with high night temperatures adversely affecting flower initiations of tomato with the ultimate effect on yield. Again, the finding partly supports the conceptual framework which explains that high temperature adversely affects soil moisture content causing a significant decrease in crop yield. However, the result is inconsistent with the study of Tshiala and Olwoch (2010) who observed an increase in tomato yield in the wake of high temperature in the Limpopo Province, South Africa, between the periods of 1971 and 2006. The reason for the increase in tomato yield was due to the application of good farming practices, fertiliser application and the employment of irrigation. Therefore, the study‟s hypothesis that there is no significant relationship between temperature and tomato yield is rejected ($P < .05$) and hence the alternative hypothesis that temperature has a significant relationship with tomato yield is maintained.

Again, the contribution of rainfall in predicting tomato yield was also statistically significant, (beta = -.27, $P < .05$) and hence the hypothesis that rainfall has no significant relationship with tomato yield is rejected and the alternative hypothesis that rainfall has a significant relationship with tomato is failed to be rejected. This findings supports the study of Mensah *et al*, (2013) who alluded that excessive rainfall (above 750mm) reduces light intensity and thus adversely affects the yield of tomato as well as increases the incidence of fungal diseases of the crop.

Another implication is that excessive annual rainfall can also affect the yield of tomato. This result is also consistent with the study of Kalibbala (2011) who found that high rainfall could be harmful to tomato crops and affect its yield. The beta value of temperature and rainfall indicates that the effect of temperature on tomato is higher than that of rainfall. The implication is that, even though tomato is considered a warm season crop, a higher temperature above its threshold can be detrimental to the crop.

4.4 SUMMARY

This chapter involved the analyses of the climate variability trend, and the effects of the observed climatic variations on tomato production in the Offinso North District. The chapter specifically explored the temperature and rainfall variability trend as well as the effects of the climatic variables (temperature and rainfall) on tomato production by controlling other confounding variables. The result of the temperature trend was not different from the report of the IPCC"s AR5 which projected temperature to increase in most parts of the world especially, countries in sub-Saharan Africa. However, the result contradicts the report of the Fourth Assessment Report of the IPCC which asserts that, the changing climate will cause a reduction in rainfall and hence impact water resources in most parts of Africa. The responses gathered from the farmers show that climate variability may also be caused by people disobeying God or gods. Their perceptions add to the discourse about the causes of climate variability which are primarily believed to be either anthropogenic or natural or both. The study again unearths some of the effects of climatic variations on tomato production. It is evident that high temperature and high rainfall causes a reduction in tomato yield and hence affects the general production of tomato. The hypothesis that temperature has no significant relationships with tomato yield was rejected. Again, the hypothesis that rainfall has no significant relationships with tomato yield was also rejected. The subsequent chapter examines farmers" perception of climate variability effects on tomato production, and the adaptation strategies they have employed to the effects of the climatic variations in the Offinso North District.

CHAPTER FIVE TOMATO FARMERS' PERCEPTIONS AND ADAPTATION STRATEGIES

TO CLIMATE VARIABILITY

5.1 INTRODUCTION

This chapter unravels the perceptions of tomato farmers about the effects of climate variability on tomato production and the adaptation strategies they have employed in response to the effects of the climate variability. The analyses of the perceptions of farmers and their adaptation strategies are preceded by their socio-demographic characteristics. The chapter therefore teases out how the farmers perceive climate variability effects using descriptive statistics and thematic analysis of the FGD. Structured interviews and observations were also employed to elicit from the farmers their adaptation to climate variability risks.

This chapter is thus divided into four major sections. Following this introduction, Section 5.2 describes the socio-demographic characteristics of the farmers; while Section 5.3 explores the perception of farmers about the effects of the climate variability on tomato production. Section 5.4 underscores the various adaptation strategies of farmers in response to the effects of the climatic variations and Section 5.5 sums up the results.

5.2 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

This section describes the socio-demographic characteristics of the farmers in the study communities in the district. Some of the socio-demographic characteristics of the farmers that are described include sex, age and their educational background. Appropriate diagrams have been used to represent the information to help provide a quick and vivid visual impression.

5.2.1 Sex characteristics of the farmers

This section describes the sex characteristics of the farmers in the study communities. To appreciate the sex variation in the communities, graphical representation is used. Table 5.1 summarises the sex distribution of respondents in the communities under study.

Table 5.1: Sex distribution of respondents

Sex	Akomadan		Afrancho		Nkenkaasu		Total	
	No.	***%***	**No.**	***%***	**No.**	***%***	**No.**	***%***
Male	105	*66.0*	103	*70.1*	54	*75.0*	262	*69.3*
Female	54	*34.0*	44	*29.9*	18	*25.0*	116	*30.7*
Total	**159**	***100***	**147**	***100***	**72**	***100***	**378**	***100***

Source: Field data (2014)

Generally, Table 5.1 shows that, out of the total respondents (378), 262 of them (69.3%) were males while 116 (30.7%) were females. In terms of their spatial distribution the study observed a similar general pattern where the males formed the majority in all cases. Out of the total respondents of farmers in Akomadan, 105 of them (66.0%) were males while 54 respondents (34.0%) were females. Again, in Afrancho, out of the total respondents of 147, 103 of these respondents (70.1%) were males while 44 respondents (29.9%) were females. The situation was not different in Nkenkaasu where out of the total of 72 respondents, 54 were males and 18 (25.0%) were females. This implies that a greater proportion of the respondents were males with the females forming the least percentage group. Again, the sex distribution gives credence to the fact that tomato farming in the district is dominated by males. This could be attributed to the labour and energy demands of tomato cultivation. Figure 5.1 is a diagrammatic representation of the sex distribution of the respondents.

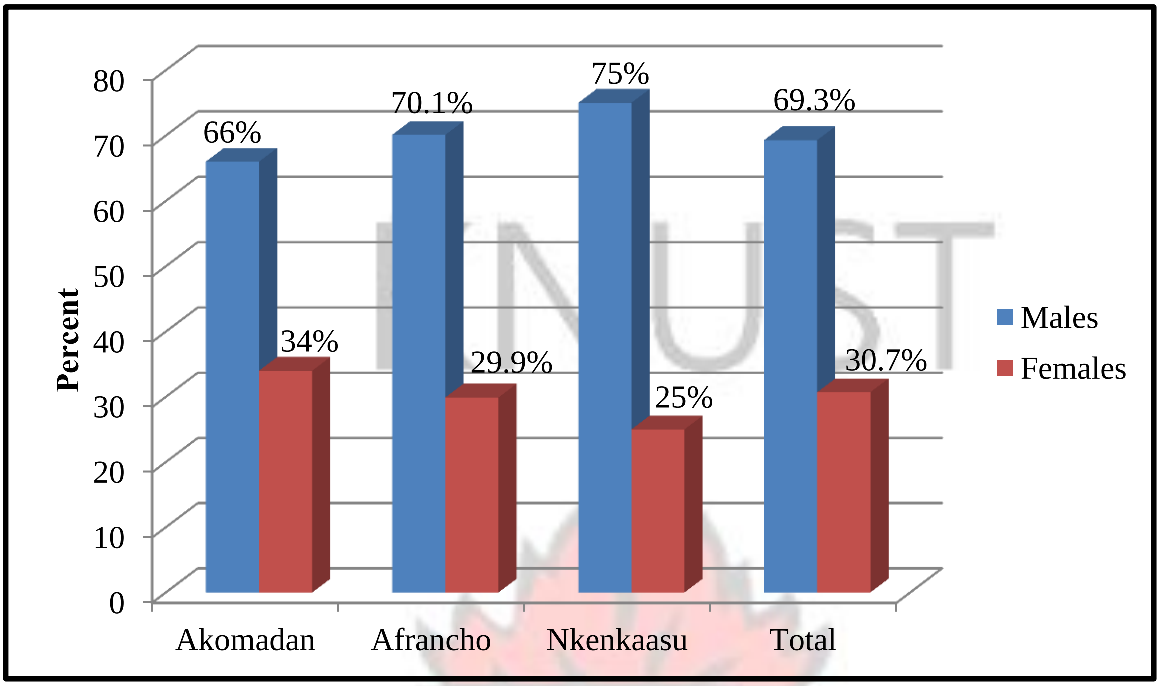


Figure 5.1: Sex distribution of respondents

Source: Field data (2014)

5.2.2 Age distribution of the farmers

This section discusses the age distribution of the farmers in the study communities. The age variation of the farmers is analysed to ascertain the age differentials of the farmers engaged in tomato cultivation in the district. Table 5.2 shows the distribution of the age differentials of the farmers in the study communities.

Generally, majority of the farmers (155 or 41%) were between the ages of 31 and 40. This was followed by those between the ages of 41 and 50 with a frequency of 150 (39.7%) of the total respondents. Again, 32 respondents (8.5%) were aged between 20 and 30 years.

Table 5.2: Age distribution of respondents

Age	Akomadan				Sub-Total		Afrancho				Sub-Total		Nkenkaasu				Sub-Total		Overall Total	
	Male		Female				Male		Female				Male		Female					
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
20-30	10	*9.5*	6	*11.1*	16	*10.1*	6	*5.8*	4	*9.1*	10	*6.8*	4	*7.4*	2	*11.1*	6	*8.3*	32	*8.5*
31-40	50	*47.6*	25	*46.3*	75	*47.2*	40	*38.9*	22	*50*	62	*42.2*	13	*24.1*	5	*27.8*	18	*25*	155	*41*
41-50	30	*28.6*	19	*35.2*	49	*30.8*	49	*47.6*	16	*36.4*	65	*44.2*	26	*48.1*	10	*55.5*	36	*50*	150	*39.7*
>50	8	*7.6*	4	*7.4*	12	*7.5*	6	*5.8*	2	*4.5*	8	*5.4*	7	*13*	0	*0.0*	7	*9.8*	27	*7.1*
Total	105	*100*	54	*100*	**159**	*100*	103	*100*	44	*100*	**147**	*100*	54	*100*	18	*100*	**72**	*100*	**378**	*100*

Source: Field data (2014)

This was followed by farmers who were over 50 years with a frequency of 27 forming 7.1 percent. Since majority of the farmers were within the age group of 31 and 40, the implication is that the farming population is generally youthful and has a relatively greater potential for sustainable tomato production. However, the relatively larger number of the farmers within the age category of 41 and 50 also implies that the farming population is ageing gradually and therefore has the tendency to affect the tomato business.

Spatially, the age distribution of the respondents in the communities portrays a different picture. Unlike Akomadan where the farming population is youthful and probably has greater access to land, it was observed in Nkenkaasu that majority of the respondents, 36 (50%) fell within the age bracket of 41-50 which implies that the farming population in that particular community is ageing and therefore has the potential to affect the sustainability of the tomato business. Similarly, the situation was not different in Afrancho where majority of the farmers (44.2%) fell within the same age bracket (41-50) signifying an ageing farming population which may have far-reaching effects on their adaptation practices. The reason why the aged dominate in tomato cultivation in these two communities may be due to the fact that, the aged own the lands and therefore have greater access to the land which invariably pushes them into the farming business. Again, the low number of the youth into tomato business could be attributed to the fact that, majority of the youth had formal education as compared to the aged. As a result, the aged have no choice but to engage in farming which is the predominant occupation in the area.

In terms of the sex distribution of the age structure across the communities, it is evident that majority of the male respondents, 50 (47.6%) out of the total male respondents of 105 at Akomadan were between the ages of 31-40 which implies a youthful farming population with the potential to sustain tomato production in the community. This was followed those between the ages of 41 and 50 who had a frequency of 30 forming 28.6 percent. This indicates an ageing farming population with the implication of threatening the sustainability of tomato production in the community. Also, 10 male respondents (9.5%) were aged between 20 and 30. Again, 8 male respondents (7.6%) were aged above 50 years.

The picture was not different as majority of the female farmers, 25 (46.3%) out of the total of 54 were aged between 31 and 40 years. This was followed by a relatively larger number of the female farmers, 19 (35.2%) who were aged between 41-50 years. Also, 6 female respondents (11.1%) were aged between 20 and 30. Again, 4 female respondents (7.4%) were aged above 50 years. This implies that, even though the female farming population is youthful with the potential to sustain tomato production, the ageing nature of the female farmers is worrying as it has the ability to affect the quantity of tomato produced in the community. Again, the ageing female farming population also means that they will be employing more labourers on their farms because of their waning strength.

In the case of Afrancho, majority of the male respondents, 49 (47.6%) out of the total of 103 respondents were aged between 41 and 50 years. This was followed by those who were aged between 31 and 40 years with 40 respondents (38.9%). Also, 6 male respondents (5.8%) were aged between 20 and 30. Similarly, 6 male respondents (5.8%) were those aged above 50 years. The age structure of the male farmers in the community indicates that the farming population of male farmers at Afrancho is ageing and therefore has a greater potential to affect the quantity of tomato produced in the community. However, the situation was quite different as majority of the female farmers, 22 (50%) out of the total female respondents of 44, rather were those aged between the ages of 31 and 40. This was followed by those who were aged between 41 and 50 with 16 respondents (36.4%). Also, 4 female respondents (9.1%) were aged between 20 and 30 years. Again, 2 respondents (4.5%) were female respondents above 50 years. This means that more female farmers at Afrancho were youthful and can contribute to tomato production in the community. However, because of their strength, there is the tendency that they will hire more labourers to work for them on their farms in order to produce more.

The situation was also slightly different at Nkenkaasu. Here, out of the total of 54 male respondents majority of them (26 or 48.1%) were aged between 41 and 50. This was followed by those who were aged between 31 and 40 years with 13 respondents (24.1%). Also, 7 male respondents forming 13% were those aged above 50 years. Again, 4 male respondents (7.4%) were those aged between 20 and 30 years. This implies that the male farming population is ageing in the community and therefore likely to reduce the quantity of tomato produced in the area.

Similarly, out of the total female respondents of (18) majority of them, 10 (55.5%) were aged between 41 and 50 years which indicates an ageing population with the potential to affect the production of more tomatoes in the community. This was followed by those who were aged between 31 and 40 with 5 respondents (27.8%). Also, 2 female respondents (11.1%) were aged between 20 and 30 years. However, none of the female respondents was above 50 years.

On the whole, it can therefore be concluded that, due to the youthful nature of the male farming population, tomato business at Akomadan has a brighter future unlike Afrancho and Nkenkaasu where the male farming population is ageing. Moreover, female farmers‟ contribution to the cultivation of tomatoes in the area cannot be underestimated. Notwithstanding their physical nature, they are able to engage the services of labourers in their farming business at the various stages of production.

5.2.3 Educational status of respondents

This section describes the level of education of the farmers in the study area. The levels of education identified include: Primary, Middle/Junior High School (JHS) and Secondary. Operationally, farmers who have attained these levels are those who have successfully completed those levels, possibly, with appropriate certificates. Table 5.3 shows the distribution of the educational status of the farmers in the study area.

Generally, it is evident that, out of the total 378 respondents, majority of them (168 or 44.4%) had no formal education. This was followed by farmers who had formal education up to the Middle school or JHS level (134 or 35.5%) of the total respondents. Again, 56 respondents (14.8%) had education up to the primary school level. The least number of respondents, 20 (3.7%) were farmers who had education up to the secondary school level. This implies that majority of the respondents had no or little educational attainment which may influence their adaptive strategies through the adoption of traditional strategies instead of scientific strategies in responding to the impact of the climate variability.

Table 5.3: Educational level of respondents

Education	Akomadan				Sub-Total		Afrancho				Sub-Total		Nkenkaasu				Sub-Total		Overall Total	
	Male		Female				Male		Female				Male		Female					
	No.	*%*	**No**	*%*	**No.**	*%*	**No.**	*%*	**No**	*%*	**No**	*%*	**No**	*%*	**No**	*%*	**No**	*%*	**No.**	*%*
Primary	14	*13.3*	10	*18.5*	24	*15.0*	8	*7.8*	7	*15.9*	15	*10.2*	13	*24.1*	4	*22.2*	17	*23.6*	56	*14.8*
Middle/JHS	47	*44.8*	21	*38.9*	68	*42.8*	23	*22.3*	13	*29.5*	36	*24.5*	21	*38.9*	9	*50.0*	30	*41.7*	134	*35.5*
Secondary	5	*4.8*	1	*1.9*	6	*3.8*	9	*8.7*	5	*11.4*	14	*9.5*	0	*0.0*	0	*0.0*	0	*0.0*	20	*5.3*
None	39	*37.1*	22	*40.7*	61	*38.4*	63	*61.2*	19	*43.2*	82	*55.8*	20	*37.0*	5	*27.8*	25	*34.7*	168	*44.4*
Total	105	*100*	54	*100*	**159**	*100*	103	*100*	44	*100*	**147**	*100*	54	*100*	18	*100*	**72**	*100*	**378**	*100*

Source: Field data (2014)

However, the spatial distribution portrays some variations regarding the educational levels of the respondents in the communities. With respect to Akomadan and Nkenkaasu, majority of the respondents (68 and 30) forming 42.8 percent and 41.7 percent respectively had attained education up to the Middle/JHS level. The level of education among farmers in these two communities has the potential to influence their adaptive capacities and strategies unlike Afrancho where majority of the respondents 82 (55.8%) had no formal education. The implication is that the low level of education among respondents in Afrancho can affect their knowledge on scientific adaptation strategies. Again, notwithstanding the level of education of the farmers, and the fact that the farming population in this community is ageing, their farming experience plays a major role in determining their adaptive measures.

With regards to the educational levels and the sex differentials of the respondents across the communities, it is evident that majority of the male farmers, 47 (44.8%) out of the total male respondents of 105 at Akomadan had education up to the Middle or JHS level. This was followed by male farmers who had no formal education at all with a frequency of 39 (37.1%) of the total male respondents. Again, 14 respondents (13.3%) had education up to the primary school level. The least number of male respondents (5) had education up to the secondary school level and they constitute 4.8 percent. On the contrary, more female respondents, 22 (40.7%) out of the total female respondents of 54 at Akomadan had no formal education at all. This was followed by female farmers who had education up to the Middle or JHS level with a frequency 21 of forming 38.9 percent of the total female respondents. It was also revealed that, 10 respondents (18.5%) had education up to the primary school level. The least number of female respondents (1 or 1.9%) had education up to the secondary school level. This means that the level of education of the male farmers were higher than that of the female farmers in the community. The implication is that the male farmers at Akomadan may be influenced by their level of education to use agrochemicals to boost tomato production.

At Afrancho, the study revealed that, out of the total male respondents, 63 of them forming 61.2 percent had no formal education at all. This was followed by 23 respondents (22.3%) who had education up to the Middle or JHS level. Also, 9 respondents (8.7%) had education up to the secondary school level while 8 respondents (7.8%) had education up to the primary school level. However, there were some variations regarding the level of education of the female respondents in the community.

Out of the total female respondents of 44, 19 of them (43.2%) had no formal education. This was followed by 13 female respondents (29.5%) who had education up to the Middle or JHS level. Also, 7 respondents (15.9%) had education up to the primary school level with the least respondents, 5 (11.4%) attaining education up to the secondary school level. This implies that majority of both male and female respondents in the community had no formal education which could go a long way to affect their adaptive capacities.

In the case of Nkenkaasu, the study showed that out of the total male respondents of 54, 21 of them (38.9%) had education up to the Middle or JHS level. A relatively larger number of the male respondents, 20 (37.0%) had no formal education at all. Also, 13 respondents (24.1%) had education up to the primary school level. Again, none of the male respondents had education up to the secondary school level. Conversely, out of the total of 18 female respondents, 9 of them (50%) had education up to the Middle or JHS level. This was followed by 5 female respondents (27.8%) who had no formal education. Also, 4 respondents (22.2%) had education up to the primary school level. Again, none of the female respondents had education up to the secondary school level.

The implication is that the educational level of the female respondents has a greater potential of influencing their adoption and implementation of sound adaptive strategies to improve the yield of tomato cultivation in the community.

5.3 PERCEPTIONS OF THE EFFECTS OF CLIMATE VARIABILITY ON TOMATO PRODUCTION

The issue of perception is very vital in climate variability analysis as people have varied views and opinions on the phenomena across space and time (Kotir, 2011). This section therefore explores how farmers perceive the effects of climate variability on tomato production in the Offinso North District. Both quantitative and qualitative techniques were adopted in analysing the data. Cross-tabulations and Chi-square analyses have been employed to ascertain some relationships between variables such as the sex of farmers and their perception of climate variability effect. While the cross-tabulation provided some descriptive statistics, the Chi-square test showed the relationships between the variables within some significant level. The qualitative data from the FGD were analysed thematically to add depth to the quantitative analyses.

Generally, the overall results show that out of the total of 378 valid cases, majority of the respondents, (171 or 45.2%) perceived the effects of climate variability on tomato to be poor yield followed by 102 respondents (27%) who perceived the effects to be inadequate tomato supply. Also, 76 respondents (20.1%), perceived the effect of climate variability on tomato to be incidence of tomato disease with the least respondents (29 or 7.7%) who perceived climate variability to affect the livelihood of farmers. The above results implies that, majority of the farmers perceived that climate variability could have some degree of impact on tomato yield with the overall effect on its sustainable supply.

Table 5.4: Perceptions of climate variability effects on tomato production

Perception of climate variability effects	Akomadan				Sub-Total		Afrancho				Sub-Total		Nkenkaasu				Sub-Total		Overall Total	
	Male		Female				Male		Female				Male		Female					
	No.	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*	**No.**	*%*
Poor tomato yield	51	*48.6*	18	*33.3*	69	*43.4*	58	*56.3*	14	*31.8*	72	*49*	24	*44.4*	6	*33.3*	30	*41.7*	171	*45.2*
Incidence of tomato disease	19	*18.1*	10	*18.5*	29	*18.6*	9	*8.7*	10	*22.7*	19	*12.9*	18	*33.3*	10	*55.7*	28	*38.9*	76	*20.1*
Effects on livelihood	1	*1.0*	1	*1.9*	2	*1.3*	19	*18.5*	8	*18.2*	27	*18.4*	0	*0*	0	*0*	0	*0.0*	29	*7.7*
Inadequate tomato supply	34	*32.3*	25	*46.3*	59	*37.1*	17	*16.5*	12	*27.3*	29	*19.7*	12	*22.3*	2	*11.1*	14	*19.4*	102	*27.0*
Total	105	*100*	54	*100*	**159**	*100*	103	*100*	44	*100*	**147**	*100*	54	*100*	18	*100*	**72**	*100*	**378**	*100*

Source: Field data (2014)

This supports the findings of Kalibbala (2011) who exemplifies in one study that climate variability, especially temperature variability causes a reduction in tomato yield. This was also supported during the FGD when a male discussant retorted that:

> "*In fact prolonged drought and erratic rainfall affects our yield to the extent that, it even becomes a disincentive to go to the farm. This is due to the fact that, you may not even harvest a box of tomato from the farm*" (Focus Group Discussion, 2014).

This is also in consonance with the views of the Field Officer of the District Directorate of MoFA when he remarked that:

> "*Tomato is a warm season crop which needs an optimum temperature of about 28^{0}C for survival. However, a high temperature beyond its capacity causes scorching of the tomato plant and increases the incidence of decay which affects the tomato fruits*" (In-depth Interview, 2014).

Spatially, there was some variation regarding respondents‟ perceptions on the effect of the climatic variations on tomato production. Majority of the respondents, 59 (37.1%) in Akomadan perceived climate variability to affect tomato supply more than that of Afrancho and Nkenkaasu. Their views may have been informed by the greater loss of tomato production they experienced during the last season which culminated in some of the farmers changing their farm locations with the presumption that their farm lands may be losing its fertility. Also, majority of the respondents in all the communities, perceived poor tomato yield as the major effects of climate variability on tomato production. In Akomadan, out of the 159 respondents, 69 (43.4%) perceived the effects of climate variability on tomato production to be poor tomato yield. In the case of Afrancho, out of the total respondents of 147, 72 of them forming

49 percent perceived climate variability to adversely affect tomato yield. The case of Nkenkaasu was not different as 30 respondents out of the total of 72 (41.7%) also supported the idea of climate variability negatively affecting tomato yield. The implication is that the decrease in tomato yield will adversely affect food security which may threaten the achievement of the Millennium Development Goal 1. In the area of farmers‟ perception on the effect of climate variability on the incidence of tomato disease, 28 respondents (38.9%) at Nkenkaasu perceived climate variability to cause an incidence of tomato disease which can affect the tomato crop. The reason may be due to the presence of forest in the area which influences evapotranspiration and causes some slight increase in rainfall with the potential to cause blight to tomatoes. Asante *et al*. (2010) explain that blight affects tomato and cause a reduction in yield. A discussant in the FGD also had this to share:

> "*When the rains come at a time the tomatoes do not need water especially during the ripening stage, „brighten" affect the tomato. This disease attacks the tomato fruit and causes it to become pale and starts to decay: as a result, we do not get much yield and recouping what has been invested in the farm becomes a serious problem*" (Focus Group Discussion, 2014).

On farmers‟ perception of climate variability affecting their livelihood, 27 (18.4%) out of the total of 29 respondents at Afrancho perceived climate variability affecting their livelihoods more than 2 (1.3%) respondents of Akomadan, and Nkenkaasu, 0 (0%). The reason may be that the respondents at Afrancho may have ineffective alternative livelihood activity to support their major livelihood activity (tomato production). Therefore, in the event of climate variability risks, such people with ineffective alternative livelihood assets are likely to feel the impact more than those with some level of effective livelihood assets and opportunities. Also, the reason why respondents at Nkenkaasu did not perceive climate variability to affect their livelihoods may be due to the fact that farmers in that community are able to implement effective adaptation strategies that are helping them to withstand the pressures of the climatic variations. Some of these adaptation strategies could be offfarm adaptation strategies such as migration that helps them to get alternative livelihood assets elsewhere to improve their livelihood outcomes.

With respect to the sex distribution across the communities, it is evident that, out of 105 male respondents, majority of them, (51 or 48.6%) at Akomadan perceived the effect of climate variability to be poor tomato yield. This was followed by 34 respondents (32.3%) who perceived the effect to be inadequate tomato supply. Also, 19 male respondents (18.1%) perceived the effect of climate variability to be incidence of tomato diseases. Finally, the least number of male respondents perceived climate variability to affect the livelihood of farmers. The picture was quite different as majority of the female farmers, 25 (46.3%) out of the total of 54 rather perceived the effect of climate variability to be inadequate tomato supply. This was followed by those who perceived climate variability to be poor tomato yield (18 or 33.3%). Also, 10 female respondents (18.5%) perceived the effect of climate variability to be incidence of tomato diseases. The least number of female respondents, (1 or 1.9%) perceived climate variability to affect the livelihood of farmers in the community. The foregone results thus far show the variation in perception of the male and female respondents at Akomadan. While majority of the male respondents perceived climate variability to affect tomato yield, the female respondents rather perceived the effect of climate variability to be inadequate tomato supply. It is possible that because women cook for the family, they use a lot of the tomato and hence become significantly affected when tomato decreases in supply.

In the case of Afrancho, out of the total of 103 male respondents, majority of them, 58 (56.3%) perceived the effect of climate variability to be poor tomato yield. This was followed by those who perceived climate variability to affect the livelihood of farmers (18.5%). Also, 17 female respondents (16.5%) perceived the effect of climate variability to be inadequate tomato supply. The least group of respondents (9 or 8.7%) who perceived the effect of climate variability to be the incidence of tomato diseases were. On the female perception on climate variability effect on tomato, majority of them, 14 (31.8%) out of 44 female respondents perceived the effect of climate variability to be poor crop yield. This was followed by those who perceived climate variability to affect the livelihood of farmers (27.3%). Also, 10 female respondents (22.7%) perceived the effect of climate variability to be incidence of tomato disease. The least number of female respondents, (8 or 18.2%) perceived climate variability to affect the livelihood of farmers. This implies that tomato farmers in this particular community perceive climate variability to have adverse effect on tomato yield which will consequently affect the supply of tomato for human consumption.

At Nkenkaasu, majority of the male respondents, 24 (44.4%) out of 54 total respondents perceived the effect of climate variability to be poor tomato yield. This was followed by those who perceived the effect to be incidence of tomato disease (33.3%). Also, 12 male respondents (22.3%) perceived the effect of climate variability to be inadequate tomato supply. None of the male respondents perceived climate variability to affect the livelihood of farmers in the community. The situation was quite different as majority of the female respondents, (10 or 55.7%) out of the total of 18 female respondents perceived the effect of climate variability on tomato to be incidence of tomato disease. Their perception may be influenced by the kind of tomato they harvest from the farm or the kind of spoilt tomato they experience at the farm. This was followed by those who perceived climate variability leads to poor tomato yield (33.3%). Also, 2 female respondents (11.1%) perceived the effect of climate variability on tomato production to be inadequate tomato supply. Finally, none of the female respondents perceived climate variability to affect the livelihood of farmers in the community.

Generally, it can be observed from the results that majority of the male respondents across the communities under investigation (Akomadan, Afrancho and Nkenkaasu) perceived the effect of climate variability on tomato production to be poor tomato yield. However, the perceptions of females were generally dispersed with regard to their spatial distribution. Among the female respondents at Afrancho majority of them perceived the effect of climate variability on tomato production to be poor tomato yield, whilst majority of the female respondents at Akomadan rather perceived the effect of climate variability on tomato production to be inadequate tomato supply. Also, majority of the female respondents at Nkenkaasu perceived the effect of climate variability to be incidence of tomato disease. Therefore, there seem to be some linkages between the male and female perception of climate variability effect on tomato farming. The perceived effect of poor tomato yield has a rippling effect on the adequacy of tomato supply and hence affects the livelihood of farmers.

To further test the relationships between the sex groups and their perception of climate variability effects, cross-tabulations and the Pearson Chi-square were used. The results indicates that, the percentage of males who perceived the effect of climate variability on tomato production to be inadequate food supply were 11 times (30.2%-

19.8%) more than that of the females. A similar remarkable difference was also observed for the category of incidence of crop diseases where the percentage of the males was 14 times (24.4%-10.3%) more than that of the females. However, the percentage of males who perceived the effect of climate variability on tomato production to be poor crop yield was 9 times (42.4%-51.7%) less than that of the females. Similarly, the percentage of males who perceived climate variability to affect farmers‟ livelihood was 15 times (3.1%-18.1%) less than that of the females (See Table 5.5).

Table 5.5: Cross-tabulation of the perceived effects of climate variability on tomato production by sex

			Sex		
			Male	Female	Total
How do you perceive the effect of climate variability on tomato	Inadequate food supply	Count	79	23	102
		Expected Count	70.7	31.3	102.0
		% within Gender	30.2%	19.8%	27.0%
	Poor crop yield	Count	111	60	171
		Expected Count	118.5	52.5	171.0
		% within Gender	42.4%	51.7%	45.2%
	Incidence of crop disease	Count	64	12	76
		Expected Count	52.7	23.3	76.0
		% within Gender	24.4%	10.3%	20.1%
	Affects livelihood	Count	8	21	29
		Expected Count	20.1	8.9	29.0
		% within Gender	3.1%	18.1%	7.7%
Total		Count	262	116	378
		Expected Count	262.0	116.0	378.0
		% within Gender	100.0%	100.0%	100.0%

Source: Field data (2014)

The overall implication is that, while majority of the males perceived the effect of climate variability on tomato production to be inadequate tomato supply and the incidence of crop diseases, more females on the other hand perceived the effects of the climate variability on tomato production to be poor crop yield and livelihood impact.

Table 5.6: Chi-square test of the relationship between the sex of farmers and their perception of climate variability effect on tomatoes

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.401	3	.000
Likelihood Ratio	35.175	3	.000
Linear-by-Linear Association	7.221	1	.007
No. of Valid Cases	378		

0 cells (.0%) have expected count less than 5. The minimum expected count is 8.90.Source: Field data (2014)

The results clearly show that there is a relationship between the perceived effects of climate variability on tomato production and the sex of the farmers. To determine whether the relationship is statistically significant, the Chi-square test result with 5 percent significance level and 95 percent confidence level showed a significant relationship ($P<0.05$) between the sex of farmers and their perception of the effects of climate variability on tomato production and that the relationship found was not due to chance (See Table 5.6). Thus, the hypothesis that “a significant relationship exists between the effects of climate variability on tomato and the sex of farmers” is therefore validated.

5.4 FARMERS ADAPTATION STRATEGIES IN RESPONSE TO CLIMATE VARIABILITY RISK

Climate adaptation is very important because of the shocks and risks that are visited on farmers. This section therefore examines how farmers adapt to the effects of climate variability on tomato production in the Offinso North District. While some of the adaptation strategies are on-farm, others are off-farm. However, it was observed that tomato farmers employed myriads of on-farm adaptation measures as compared to the off-farm strategies. These adaptation strategies practiced by the tomato farmers reinforces the relevance of the conceptual framework adapted for the study which explains farmers preparedness in employing adaptive measures when their social and economic livelihoods are affected by the effects of climatic variations. Table 5.7 provides the results of the various on-farm and off-farm adaptation practices employed by tomato farmers in the Offinso North District.

Table 5.7: Tomato farmers adaptation strategies

Farmers adaptation strategies	**Akomadan**		**Afrancho**		**Nkenkaasu**		**Total**	
	Yes n(%)	**No n(%)**	**Yes n(%)**	**No n(%)**	**Yes n(%)**	**No n(%)**	**Yes n(%)**	**No n(%)**
Changes in farm location	60 (*37.7*)	99 (*62.3*)	38 (*25.9*)	109 (*74.1*)	20 (*27.8*)	52 (*72.2*)	118 (*31.0*)	260 (*69.0*)
Changes in crop variety	30 (*18.9*)	129 (*81.1*)	33 (*22.5*)	114 (*77.6*)	16 (*22.2*)	56 (*77.8*)	79 (*20.9*)	299 (*79.1*)
Crop diversification	123 (*77.4*)	36 (*22.6*)	96 (*65.3*)	51 (*34.7*)	52 (*72.2*)	20 (*27.8*)	271 (*71.7*)	107 (*28.3*)
Application of agrochemicals	159 (*100*)	0 (*0.0*)	147 (*100*)	0 (*0.0*)	72 (*100*)	0 (*0.0*)	379 (*100*)	0 (*0.0*)
Irrigation	52 (*32.7*)	107 (*67.3*)	28 (*19.0*)	119 (*81*)	22 (*30.6*)	50 (*69.4*)	102 (*27.0*)	276 (*73.0*)
Mixed cropping	139 (*87.4*)	20 (*12.6*)	113 (*76.9*)	34 (*23.1*)	49 (*68.1*)	23 (*31.9*)	301 (*79.6*)	77 (*20.4*)
Diversification to nonfarm activities	87 (*54.7*)	72 (*45.3*)	40 (*27.2*)	107 (*72.8*)	22 (*30.6*)	50 (*69.4*)	149 (*39.4*)	229 (*60.6*)
Migration	50 (*31.4*)	109 (*68.6*)	44 (*30.0*)	103 (*70.1*)	39 (*54.2*)	33 (*45.8*)	133 (*35.2*)	245 (*64.8*)

Source: Field data (2014)

It is evident from Table 5.7 that tomato farmers in the study area employ several onfarm and off-farm strategies in response to the shocks of climate variability. A change in farm location as an adaptive strategy was not a major practice in the area.

Generally, out of the total of 378 valid cases, 118 (31.0%) changed their farming location while majority of the respondents, (260 or 69%) did not. This means that even though some of the farmers changed their location to other places for reasons such as the loss of the soil fertility, there were still majority of the respondents who did not change location. This was re-echoed during one of the FGD session when a farmer alluded that:

> *"It is not easy changing farm location because of the tenure of land. Apart from the family land which I have my share, securing another piece of land will mean buying one. But since I don"t have money to buy one, it means I have to stick to what I have at the moment"* (Focus Group Discussion, 2014).

The result did not show much variation in terms of the spatial distribution as majority of all the respondents in the communities under investigation indicated their failure in changing the farm location. At Akomadan, out of the total of 159 respondents, 99 of them (62.3%) did not change their farm location. Also at Afrancho, out of the total of 147 respondents, 109 (74.1%) did not change their farm location. The situation was not different at Nkenkaasu where 52 respondents (72.2%) out of the total respondents of 72, also did not change their farm location. The implication of changing the location of farms into new areas could mean clearing of more forest lands for cultivating tomatoes and this could contribute to global warming through removal of trees.

On changes in crop variety as an adaptive strategy, farmers particularly stuck to their preferred variety (Pectomech). While majority of the farmers, 299 (79.1%) answered „No‟, indicating their resolve not to change the variety of tomato, only 55 (14.6%) of them responded „Yes‟ indicating that they have changed the variety of tomatoes as an adaptive measure. Farmers who failed to change the variety of the tomato alluded that they did so as a result of the fact that most buyers normally preferred some particular varieties, especially Pectomech (See Plate 5.1). Spatially, there was not much difference in the respondents‟ answers in the communities regarding their adaptation through changes in the tomato variety. Table 5.7 reveals that out of the total respondents of 159 in Akomadan, 129 (81.9%) had not changed the variety of tomato as an adaptive mechanism. Similarly, out of the total of 147 respondents in Afrancho, 114 (77.6%) maintained their tomato variety. The situation was not different from the responses of the respondents in Nkenkaasu where majority of the respondents (56 or 77.8%) also failed to change the variety of the tomato they produce. Their preference for the cultivation of Pectomech was due to the demand from the buyers. It was also observed that some of the farmers who changed their varieties preferred others like Power Rano. One of the reasons they provided was the resistance of the variety to tomato diseases (e.g. mosaic and leaf curl).

Crop diversification was also found to be an adaptive measure that was preferred by the farmers in the event of climate variability affecting tomatoes. Out of the total respondents (378), 271 (71.7%) employed crop diversification as an adaptive strategy with 107 (28.3%) failing to diversify. With an average farm size of about 2.5 acres, the farmers diversified into crops such as maize, yam, cassava and pepper on the same piece of land. The reason why majority of the farmers diversified to other crops was that it provided them the opportunity to absorb the shock of the climatic variation. This finding supports the view of Uddin *et al*. (2014) who noted that farmers adopt crop diversification to reduce the overall farm risk and expand opportunities for farm profit, which generally boost their average incomes.

Plate 5.1: Fresh Pectomech tomato

Source: Field data (2014)

Geographically, the study results revealed that out of the total of 159 respondents 123 of them (77.4%) diversified their tomato crop production. Again, out of the total of 72 respondents in Nkenkaasu, 52 (72.2%) diversified to other crops. It was also evident in Afrancho that 96 respondents (65.3%) out of the total of 147 also diversified to other agricultural crop production. This is an indication of the farmers‟ preparedness of providing other livelihood opportunities to be able to absorb the shock of the climatic variation. However, this method may not be sustainable since the diversified crops also depend on rainfall which has been unreliable.

Application of agrochemicals was found to be a major adaptive measure that was common to all the farmers in the area. Generally, it was observed that all the farmers, (378 or 100%), used agro-chemicals. Spatially, all the respondents from the three settlements applied agro-chemicals (e.g. fertiliser, furadan etc.) as an adaptive strategy to improve the fertility of the soil and to eradicate tomato diseases. Most of the farmers applied NPK 15-15-15 because they believed that, it dissolves easily and helps the crops to grow faster (See Plate 5.2).

Plate 5.2: Adaptation through application of fertiliser

Source: Field data (2014)

This finding is consistent with the study of Tshiala and Olwoch, (2010) who observed that the use of agro-chemicals especially fertiliser is a good adaptation strategy that improves tomato yield.

Irrigation as an adaptive strategy was also not popular among the farmers in the area. Out of the total of 378 respondents, majority of them (276 or 73.0%) did not practice irrigation with the minority (102 or 27.0%) employing irrigation as a strategy. Most of the farmers who did not practice irrigation explained that, irrigation involves a lot of cost, especially with respect to purchasing irrigation pipes and pumping machine. Most of the farmers also alluded that some of the nearby rivers dry up during the dry season which makes it tedious and unattractive for them to move to farther places for water. This was evident during the FGD when a discussant lamented that:

> *"Irrigation is good but if your farm is around areas where the rivers and streams are drying up, how do you irrigate. Again, proper irrigation demands a pumping machine to facilitate the process but because of money we are not able to buy such machines to irrigate our crops and we leave them to the mercy of the rains. So when the rains also fail us then problem looms"* (Focus Group Discussion, 2014).

Geographically, majority of the respondents in the communities failed to irrigate their tomato crops. However, it was observed that the number of respondents who failed to employ irrigation at Afrancho were comparatively more than those in Akomadan and Nkenkaasu. The reason was that some of the few streams around the farms were drying up making it difficult for the farmers to get enough water for irrigation. They were therefore worried about the extent of deforestation in the area especially around the water bodies which has culminated in the drying up of the streams. Plate 5.3 provides a visual impression of an irrigated farm in the study area.

Irrigation as an adaptive mechanism is seen as relevant particularly in the dry season as opined by Tshiala and Olwoch (2010) who identified irrigation as one of the major adaptive strategies that could improve the yield of tomato in the era of climate variability.

Plate 5.3: Adaptation through irrigation

Source: Field data (2014)

Mixed cropping as an adaptive strategy was preferred by most of the farmers. Out of the total of 378 valid cases, majority of the respondents (301 or 79.6%) employed the mixed cropping strategy. It was observed that tomato farmers mix tomato with crops such as okro, pepper and maize. They explained that mixing such crops with the tomatoes was one of the major means by which they were able to absorb the risk of the climatic variation. The relevance of mixed cropping was re-echoed during the FGD when a discussant noted that:

> *"In fact, almost every farmer mixes tomato with other crops such as okro, pepper and maize. The reason is to get something to fall on when the tomato fail us. At least the growing of these crops can help to reduce our cost"* (Focus Group Discussion, 2014).

Spatially, the situation was not different from the general picture in the area of farmers" adaptation strategy through mixed cropping. This was evident when a majority of 139 respondents (87.4%) out of the total of 159 in Akomadan employed mixed cropping. Also, majority of the respondents (113 or 76.9%) out of the total of 147 at Afrancho also employed mixed cropping. Similarly, out of the total of 72 respondents at Nkenkaasu (49 or 68.9%) employed mixed cropping as an adaptive mechanism. The common reason that permeated through the communities regarding their adoption of mixed cropping was that the strategy gave them the opportunity to rely on other crops as a means of improving their livelihood. Some of the crops farmers mixed with tomato crops include okro and maize (See Plate 5.4).

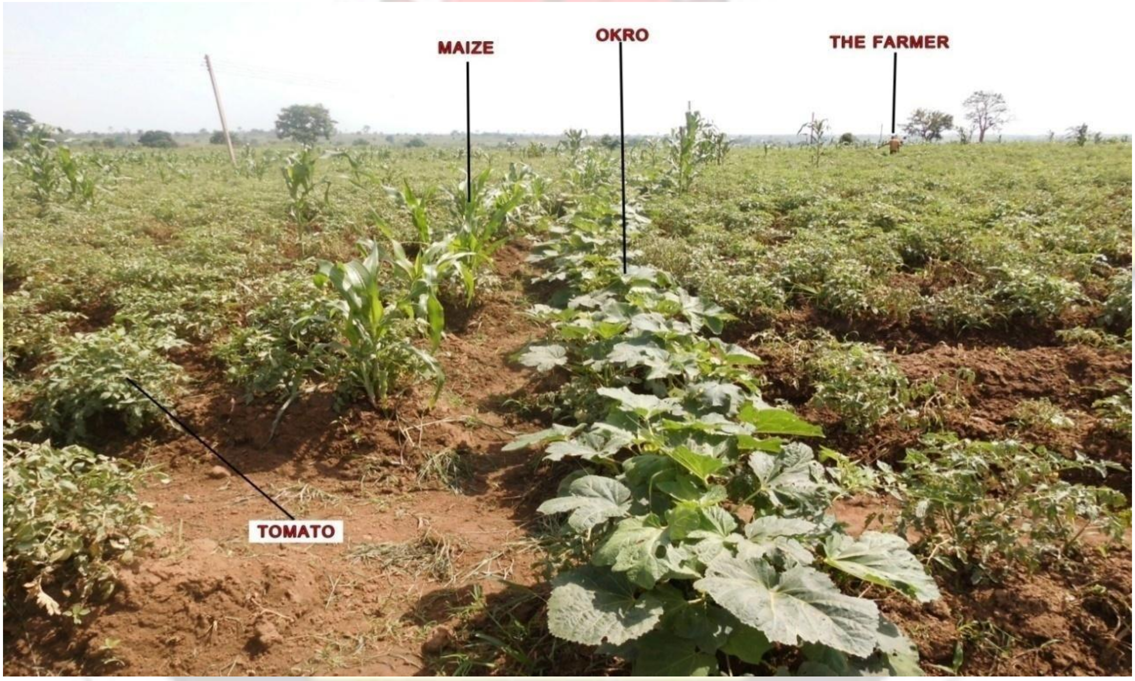


Plate 5.4: Mixed cropping adaptation strategy

Source: Field data (2014)

It is evident from Table 5.7 that tomato farmers in the Offinso North District employed some off-farm adaptation strategies in their bid to responding to the shocks of climate variability.

Diversification into non-farm activities as an adaptive measure by farmers was not popular and much preferred. This was evident when out of the total of 378 respondents, 149 (39.4%) diversified into non-farm activities such as trading, dress making, fashion designing and hair beautification, carving and rearing of farm animals. However, majority of the respondents (229 or 60.6%) did not diversify. The respondents explained that the tomato business is the main source of livelihood bequeathed to them by their forefathers. They further stated that, their experience and knowledge in the tomato business are factors that have also made them firmly glued to the tomato enterprise coupled with some financial difficulties. The implication is that if farmers continue in their old ways without diversifying into non-farm activities they are likely to experience much greater shocks in the event of failures in agriculture.

Spatially, it was glaring that even though majority of the respondents did not diversify to non-farm activities, the situation was not the same in all the study communities. Majority of the respondents in Afrancho, 107 (72.8%) and Nkenkaasu, 50 (69.4%) did not diversify to non-farm activities due to financial constraints, but a greater percent of the respondents, 87 (54.7%) at Akomadan rather diversified into a variety of nonfarm activities such as carving, trading among others. The reason may be attributed to the greater loss of tomato farmers experienced during the major season of the year where most of them could not break even. The option of diversifying to other nonfarm activities helped them to absorb more of the shocks of the climatic variations as compared to those at Afrancho and Nkenkaasu. This supports the study of RodriguezSolorzano *et al*. (2014) who intimated that engagement in non-farm activities help farmers in overcoming the pressures of the climatic variations and hence allow them to distribute the climate risks over different economic activities. However, it is important to note that some of these off-farm activities such as carving may not necessarily be sustainable. Again, this particular livelihood option has the potential to contribute more to climate variability, since it depends on the cutting down of trees which plays a major role in anthropogenic climate variability.

Migration as an adaptive strategy was also not too popular among respondent. The study revealed that majority of the respondents (245 or 64.8%) did not migrate, as compared to 133 (35.2%) of them who rather migrated to other places to search for jobs. Those who migrated moved to urban centers to seek for other livelihood opportunities to better their livelihood outcomes. In terms of spatial distribution, there were some disparities regarding their adaptation through migration. Proportionally, it was observed that majority of the respondents (54.2%) at Nkenkaasu migrated to other places as compared to respondents in Akomadan (31.4%) and Afrancho (30%). This finding tend to support the assertion by McLeman and Smit (2006) who opine that migration is a form of adaptation within a broader set of potential adaptive responses that individuals and households undertake to minimize their vulnerabilities to the pressures of environmental changes. More respondents at Nkenkaasu migrated to urban centers because most of them secured loans to finance their tomato business and therefore needed to pay off their loans from the financiers. The overall implication is that the migrants end up compounding the social problems in the cities through pressures on social facilities and congestion.

In addition to the main adaptation strategies employed by the farmers, they were also asked about the factors that necessitated the choice of their adaptation strategies. The result is presented in Figure 5.2.

It is glaring from Figure 5.2 that, farmers experience alone in tomato production influenced the selection of their adaptation strategies as majority of them, 173 (45.8%) responded in the affirmative.

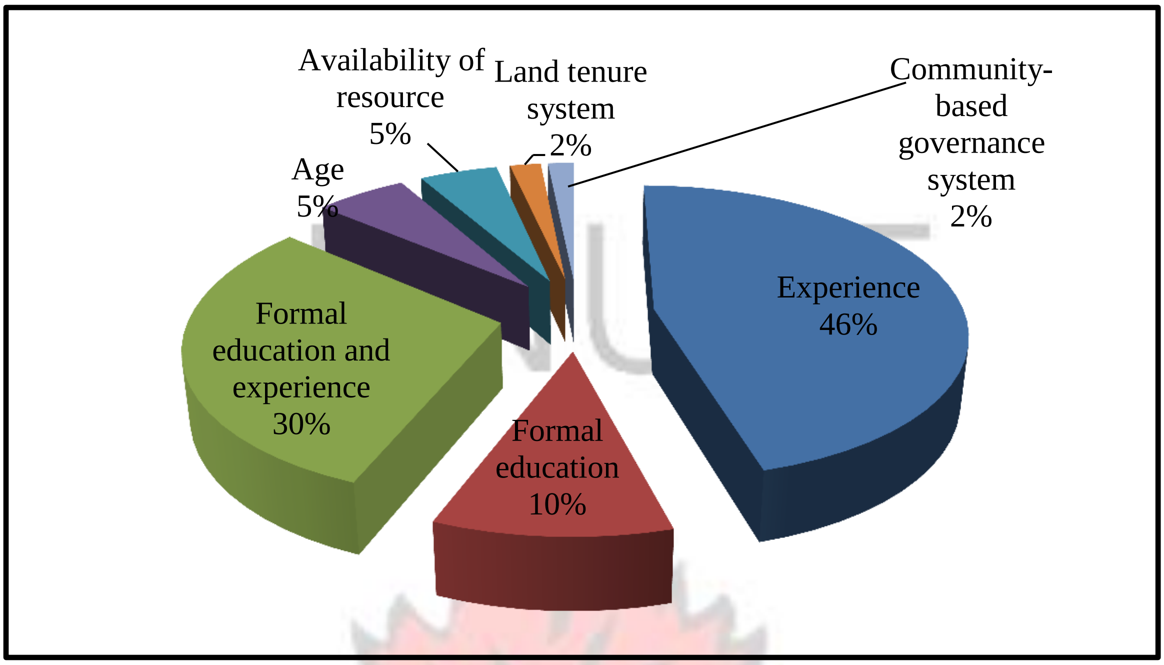


Figure 5.2: Factors influencing adaptation strategies of farmers

Source: Field data (2014)

This supports the findings of Below *et al.* (2010), who identified experience as one of the major factors that influence farmers‟ ability to adapt to climate variability. The farmers experience influencing their adaptation strategies may be due to their low level of education. Again, a sizeable number of the farmers (114 or 30.2%) identified both formal education and experience, as influencing their adaptation strategies. This was followed by formal education alone (39 or 10.3%); age, (21 or 5.6%); availability of resources, (18 or 4.8%); land tenure system, (7 or 1.9%) with community-based governance system, (6 or 1.6%) being the least factor influencing the farmers choice of adaptation practices.

The study also sourced information from the farmers about the constraints that hinder their adaptation strategies in the wake of the climate variability. The result shows that lack of access to climate information, financial constraints and high cost of agricultural inputs affect farmers‟ ability to adapt (See Figure 5.3).

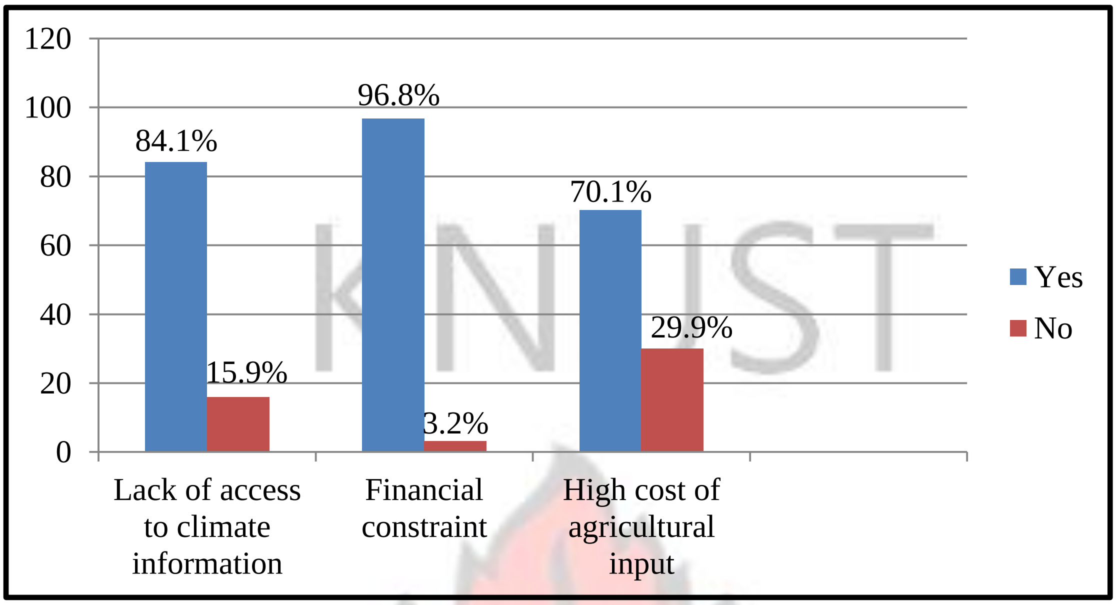


Figure 5.3: Constraints to climate adaptation strategies

Source: Field data (2014)

From the results, out of the total of 378 respondents, majority of the farmers (318 or 84.1%) identified lack of access to climate information from the district weather station as a major constraint to their adaptation strategies with 60 (15.9%) declining to this assertion. This affirms what the officer at the weather station said when he retorted that:

> "*The weather station is not meant for the farmers but for the Cocoa Research Institute of Ghana (CRIG). We are therefore not obliged to provide farmers with weather information. But I think it will help the farmers if they are furnished with the weather information*".

Moreover, an overwhelming majority of the farmers (366 or 96.8%) also admitted that financial constraint was a major challenge in their bid to adapt with only a few of them with only 12 (3.2%) objecting to that. This supports the study of Mudombi (2011) which observed that financial constraints hinder farmers" ability to adopt to climate variability. Furthermore, a greater number of the farmers (265 or 70.1%) out of the total of 378 respondents affirmed that high cost of agricultural inputs (e.g. agrochemicals) also affects their adaptation strategies with 113 (29.9%) declining to that assertion. This is in consonance with what a discussant in a focus group discussion said when he alluded that:

> "*Finance has always been a challenge to us because the chemicals we use are too expensive to buy. We apply the chemicals at several instances so when you don"t have money, you know what will happen*".

5.5 SUMMARY

The chapter discussed farmers" perception of climate variability effects on tomato production and their adaptation strategies in responding to the pressures of the variability in the Offinso North District. The chapter also expounded the descriptive statistics of some socio-demographic characteristics of the farmers. The study showed that majority of the farmers were males, 262 (69.3%) with most of the farmers, 155 (41%) aged between 31-40 years. The study also indicated that 134 (35.4%) farmers had attained education up to the JHS/Middle school level. According to the study, even though the farmers had different perceptions of the effects of climate variability, majority of them perceived the effects results in a reduction in crop yield which has adverse effects on food supply especially tomato. The study also showed some variations in perceptions regarding the study communities. Through cross-tabulations, the study identified some relationships between the sex of farmers and their perception of climate variability effect on tomato production.

This chapter also revealed that farmers employ myriads of adaptation strategies in order to operate in the observed climate variability. It was revealed that even though farmers employed a lot of adaptation strategies, majority of the farmers preferred application of agro-chemicals, mixed cropping and crop diversification. The study identified experience as the major factor influencing the farmers‟ adaptation strategies which may probably be due to the low level of education of the farmers in the district. Finally, the study observed financial constraints, lack of access to weather information and high cost of farm inputs such as agro-chemicals as challenges militating against their attempts at adaptation. These challenges can make farmers more vulnerable and impede their efforts to implement effective adaptive measures aimed at reducing the impact of climatic variations.

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

6.1 INTRODUCTION

This chapter draws the curtain of the research journey by summarizing the research process, the key findings, draw conclusions, policy recommendations and carried areas for future research. Indeed, climate variability has become a major phenomenon in recent times due to its consequence on agriculture and other areas of national development (IPCC, 2014). Against this backdrop, the study aimed at assessing the effects of climate variability on tomato production and how farmers respond through adaptation strategies in the Offinso North District.

6.2 SUMMARY

In assessing the effects of climate variability on tomato production and the adaptation strategies adopted by farmers, four specific objectives guided the study. In the first place, the study sought to analyse the trend of climate variability and the level of inter-annual variations over the past twenty years (1994-2013) in the Offinso North District. Secondly, the study analysed how climatic variations affect tomato production. Thirdly, the study also investigated how the farmers perceive the effects of climate variability on tomato production. Finally, the study assessed the current adaptation strategies of the farmers in response to the effects of climate variability.

To achieve the objectives underlining the study, a total of 378 individual farmers were randomly selected from three study communities namely; Akomadan, Afrancho and Nkenkaasu. Again, focus group discussions and in-depth interviews were used to gather qualitative responses from key informants. Participant observation was also adopted as a means to get first-hand information on the ground. Statistical analytic tools such as the descriptive statistics, regression analysis, cross-tabulation and Chisquare were used to analyse the quantitative data with the help of the IBM SPSS Statistics version 17. Also, the trend function of the Microsoft Excel software was used to analyse climate variability while the qualitative data was analysed thematically through transcription, categorisation and interconnecting.

6.3 KEY FINDINGS OF THE STUDY

Based on the results and discussion, the main findings of the study are summarized as follows:

6.3.1 Climate variability trend

The first objective was to analyse the trend of climate variability over the past twenty years (1994-2013) in the Offinso North District. The study found that both minimum and maximum temperature characteristics of the area experienced some level of variations within the stipulated years under consideration (See Figures 4.1 and 4.3). The inter-annual variability also showed several anomalies depicting variability of the climate variables over the 20 years period (See Table 4.2 and 4.4). The inter-annual variability of temperature again showed an increasing trend which suggests a warming condition in the district. Both the maximum and minimum temperatures showed an increasing trend of approximately 1 percent over the period, 1994-2013. However, the rate of increase and variations of maximum temperature within the first decade was more pronounced (1994-2002) than the second decade which showed some steady increase (2003-2013).

The study also revealed rainfall variability trend in the area even though the rate of change is not radical (See Tables 4.5 and 4.6). The analysis showed an increasing trend with less than 1 percent degree of variation. This shows that, even though rainfall increased in the area within the specified years (1994-2013), the rate of increase was not that much as compared to that of temperature. However, the interannual rainfall variability trend showed some anomalies which give evidence which portray the varying and unpredictable nature of the rainfall pattern in the District. The implication of the rising temperature being greater than the rate of rainfall increase is the fact that, there will be loss of soil moisture content due to vapourisation and evapotranspiration which can have adverse effects on the growth and yield of crops.

6.3.2 Effects of climate variability on tomato production

The second objective was to analyse how climatic variations affect tomato production. From the study, it was evident that maximum temperature had some statistically significant negative relationship with tomato yield. This means that an increase in temperature caused a significant decrease in tomato yield with some confounding variables such as soil type, application of agro-chemicals, irrigation, tomato variety and regular weeding held constant. The study further found a statistically significant negative relationship between rainfall and tomato yield. The implication is that as rainfall increases, it potentially causes a reduction in tomato yield. This means that even though tomato needs water, excessive rainfall is detrimental to the tomato crop.

6.3.3 Perceptions of the effects of climate variability on tomato production

The third objective was to investigate how the farmers perceive the effects of climate variability on tomato production. Generally, the study found some similarities in perception across the sex characteristics of the farmers. Chiefly among these similarities as showed by the sex groups on the effects of climate variability on tomato production include decreased crop yield, incidence of crop disease and impact on social and economic livelihoods. On the contrary, the study also showed some variations in perception across the sex characteristics of the farmers. It was observed that majority of the males, 7 (87.5%) perceived the effect of climate variability on tomato production to be decrease in crop yield, while more females, 6 (75.5%) on the other hand rather perceive the effects of the climate variability on tomato production to be incidence of crop diseases.

6.3.4 Tomato farmers adaptation strategies to climate variability risks

The last objective of the study was to assess the current adaptation strategies of the farmers in response to the effects of climate variability. The study revealed a number of adaptation strategies employed by the farmers some of which include; crop diversification, changes in farm location, changes in crop variety, mixed cropping, application of agro-chemicals, diversification to non-farm activities and migration. However, the study showed that majority of the farmers adopted mixed cropping, application of agrochemicals and crop diversification as on-farm adaptive mechanisms in response to the effects of climate variability. Similarly, off-farm adaptation strategies such as migration and diversification to non-farm activities were employed by majority of the farmers at Nkenkaasu and Akomadan respectively.

The study again revealed that farmers experience alone in the tomato production influenced their choice of adaptation strategies as majority of them (173 or 45.8%) responded in the affirmative with community-based governance system (6 or 1.6%) being the least factor that influenced their choice of adaptation practices. Finally, the study revealed that farmers encounter numerous challenges in their bid to adapting to climate variability. Lack of access to weather information from the Meteorological Service Department was a major challenge. This was cited by majority of the farmers (318 or 84.1%) while the least number of the farmers (60 or 15.9%) failed to accept this fact. An overwhelming majority of farmers, (366 or 96.8%) cited financial constraint as a major adaptation challenge while a few of the respondents, (12 or 3.2%) declined to this assertion. A total of 265 (70.1%) also indicated high cost of agro-chemicals as another major challenge to the farmers with 113 (3.2%) who did not agree to this assertion.

6.4 CONCLUSIONS

The study has made fairly significant contribution to previous methodologies regarding climate variability and crop production. In the first place, the study has provided a framework for further research regarding climate variability effects and adaptation strategies relationships. Unlike previous studies which adopted quantitative methodologies (Traore *et al.*, 2013; Awotoye and Matthew, 2010; Tshiala and Olwoch, 2010), this study employed the mixed methodological approach. Importantly, descriptive statistics, cross-tabulation and Chi-square techniques were used to establish the relationships and the level of significance between some variables with the help of the IBM SPSS Statistics version 17.

The hypotheses and objectives of the study were adequately validated by the findings and results. Regarding the objectives set for the study, focus group discussions and indepth interviews were used as instruments to gather qualitative data of farmers‟ perceptions of climate variability effects and their adaptation practices. The study clearly showed some variations in terms of male and female perceptions as well as some spatial variations in the perceptions of male and female respondents in their perception of climate variability effects on tomato production. To be able to bring out the nuances and holistically address the issue of perception of the farmers, inferential statistics (Chi-square) was also employed to complement the qualitative analysis. On farmers‟ adaptation practices, thematic analysis was employed to complement the descriptive analysis to help synergise the quantitative and qualitative analyses for a better appreciation of the issues.

The hypotheses were clearly validated by the findings of the survey. The study hypothesised that no significant relationship exists between temperature and tomato yield. The regression analysis indicated that, there is a statistical significant negative relationship between temperature and tomato yield ($P<0.05$) (See Table 4.2). The study further hypothesised that no relationship exists between rainfall and tomato yield. The regression analysis also showed some statistically significant negative relationship between rainfall and tomato yield ($P<0.05$) (See Table 4.2). Furthermore, the study also hypothesised that no relationship exists between the sex of farmers and their perception of climate variability effect on tomato production. The Chi-square analysis shows a statistically significant relationship between the perception of the effects of climate variability on tomato production and the sex of the farmers ($P<0.05$) (See Table 5.7).

6.5 POLICY RECOMMENDATIONS

This section of the thesis provides a policy framework that seeks to guide policy makers in designing programmes that could enhance farmers adaptive capacities to enable them respond to the pressures and risks of the climate variability as observed in the Offinso North District. Based on the findings of the study, these recommendations are proposed.

6.5.1 Developing heat resistant tomato variety

The analysis of the effect of high temperature on tomato production indicates that farmers face production losses. Since the study area is vulnerable to climate variability and tomato cultivation is the major livelihood activity for the local people, it is important to develop heat resistant tomato varieties which can withstand high temperature conditions and help improve yield. It is therefore imperative that research institutes such as the Crops Research Institute of the Center for Scientific and Industrial

Research (CRI- CSIR) in the country develops more heat resistant tomato varieties which can withstand the vagaries of the weather and improve production.

6.5.2 Provision of climate information

Access to weather information by tomato farmers could enhance adaptive strategies of the farmers. This could reduce the adverse effects of climate variability on their activities. Nevertheless, as shown by the analysis, majority of the farmers, 318 (84.1%) in the study area do not get access to weather information. Therefore, effort should be made to provide a forecast of the weather on a regular basis through the electronic media such as the radio stations in the district to update farmers on the weather dynamics to enable them plan well for their tomato activities.

6.5.3 Provision of farm inputs and fiscal empowerment

Challenges such as high cost of agro-chemicals (e.g. fertiliser, ammonia, pesticides and insecticides) and other farming inputs faced by both male and female tomato farmers were found to significantly influence their responsiveness to climate variability risks. Government should therefore ensure that appropriate measures are put in place to help farmers get access to these inputs. One of such measures is for government to subsidise these inputs to enable the poor farmers buy them for their agricultural activities which will ultimately help boost tomato production in the district. There is also the need for government and other financial institutions (e.g. Banks and Micro finance) to come in to help farmers gain access to credit facilities with less interest rate. When farmers become financially empowered, it will go a long way to enhance their adaptive capacities and strategies.

6.5.4 Establishment of tomato factory

In order to improve upon the financial capacities of the tomato farmers, and also make the tomato business more attractive, especially to the youth, it will be important if a tomato factory is built in the district to help the farmers get ready market outlets for their produce. The establishment of the factory will provide outlet to the farmers to be able to produce more tomatoes in the district and the country at large. Again, it will motivate most of the youth to venture into the tomato business which will help reduce unemployment among the youth in the area.

6.6 AREAS FOR FURTHER RESEARCH

The following propositions are areas that require further research:

- Since the study focused on the Offinso North District alone with few selected communities, there is the need for future researchers to really expand the geographical scope of the study and do a comparative study of two different districts in different climatic zones to assess the level of responsiveness and adaptation to climate variability.

- The results from this study showed some linkages between the sex of farmers and their perception on the effects of climate variability. However, it would add more to existing literature if a study is done to find out the extent to which other socio-demographic characteristics of farmers influence their perception. A multinomial analysis can be done to show the extent to which other sociodemographic characteristics of farmers influences their perception of the effects of climate variability.

REFERENCES

Abaje, I. B.1., Sawa, B. A. and Ati, O. F. (2014), "Climate variability and change, impacts and adaptation strategies in Dutsin-Ma Local Government Area of Katsina State", Nigeria, *Journal of Geography and Geology*, Vol. 6, No. 2, pp. 103-112.

Afzal, M., Mansell, M. G. and Gagnon, A. S. (2011), "Trends and variability in daily precipitation in Scotland", *Procedia Environmental Sciences,* Vol. 6, pp.15–26.

Akudugu, M. A. and Alhassan, A. R. (undated), "The climate change menace, food security, livelihoods and social safety in Northern Ghana", *International Journal of Sustainable Development and World Policy,* Vol. 1, No. 3, pp. 8095.

Anley, Y, Bogale, A. and Haile-Gabriel, A. (2007), "Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia", *Land Degradation and Development,* Vol.18, pp. 289–302.

Antwi-Agyei, P., Dougill, A. J. and Stringer, L. C. (2013), "Barriers to climate change adaptation in sub-Saharan Africa: evidence from northeast Ghana and systematic literature review", Centre for Climate Change Economics and Policy Working Paper No. 154, pp. 12, http://www.cccep.ac.uk.

Appiagyei, F. (2010), *"Effects of two neem kernel extracts in the control of whitefly (BemisiaTabaci) on tomato",* A thesis submitted to the Department of Theoretical and Applied Biology, In partial fulfillment of the requirements for the degree of Master of Science (Environmental Science), Kwame Nkrumah University of Science and Technology.

Arku, F. S. (2013), "Local creativity for adapting to climate change among rural farmers in the semi-arid region of Ghana", *International Journal of Climate Change Strategies and Management,* Vol. 5, No. 4, pp. 418-430.

Asante, B. O., Osei, M. K., Dankyi, A. A., Berchie, J. N., Mochiah, M. B., Lamptey, J. N. L.., Haleegoah, J., Osei, K. and Bolfrey-Arku, G. (2013), "Producer characteristics and determinants of technical efficiency of tomato based production systems in Ghana", *Journal of Development and Agricultural Economics*, Vol. 5, No. 3, pp. 92-103.

Assessment of Impact and Adaptation to Climate Change- AIACC, (2006), *Food security, climate variability and climate change in Sub Saharan West Africa*, International START Secretariat, Washington D. C.

Attoh, C., Martey, E., Kwadzo, G. T. M., Etwire, P. M. and Wiredu, A. N. (2014), "Can farmers receive their expected tomato price in Ghana?: A probit regression analysis", *Sustainable Agriculture Research*, Vol. 3, No. 2, pp. 1623.

Awotoye, O. O. and Matthew, O. J. (2010), "Effects of temporal changes in climate variables on crop production in tropical sub-humid South-western Nigeria", *African Journal of Environmental Science and Technology,* Vol. 4, No. 8, pp. 500-505.

Ayanlade, A., Odekunle, T. O. and Orimoogunje, O. O. I. (2010), "Impacts of climate variability on tuber crops in Guinea Savanna part of Nigeria: A GIS approach", *Journal of Geography and Geology*, Vol. 2, No. 1, pp. 27-35.

Bagamba, F., Bashaasha, B., Claessens, L. and Antle, J. (2012), "Assessing climate change impacts and adaptation strategies for smallholder agricultural systems in Uganda", *African Crop Science Journal*, Vol. 20, No. 2, pp. 303 – 316.

Bakri, H. H. and Abou-Shleel, S. M. (2013), "Economic impacts of climatic changes on some vegetable crops in Egypt", *World Journal of Agricultural Sciences,* Vol. 9, No. 4, pp. 361-368.

Basak, J. K. (2009), "*Climate change impacts on rice production in Bangladesh: Results from a model",* Unnayan Onneshan-The Innovators, A Center for Research and Action on Development, Bangladesh.

Bekele, W. and Drake, L. (2003), "Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area", *Ecological Economics,* Vol. 46, pp. 437–51.

Below, T., Artner, A., Siebert, R. and Sieber, S. (2010), "Micro-level practices to adapt to climate change for African small scale farmers: a review of selected literature", IFPRI Discussion Paper 00953.

Bita, C. E. and Gerats, T. (2013), "Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops", *Frontiers in Plant Science*, Vol. 4, pp. 273.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. and Herrero, M. (2013), "Adapting agriculture to climate change in Kenya: Household and communities strategies and determinants", *Journal of Environmental Management*, Vol. 114, pp. 26-35.

Bryant, C. R., Smit, B., Brklacich, M., Johnston Thomas, R., Smithers, J., Chiotti, Q. and Singh, B. (2000), "Adaptation in Canadian agriculture to climatic variability and change", *Climate Change,* Vol. 45, pp. 181–201.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J. and Ringler, C. (2014), "Climate change and agriculture: Impacts and adaptation options in South Africa", *Water Resources and Economics,* Vol. 5, pp. 24–48.

Campos, M. Velázquez, A. and McCall, M. (2014), "Adaptation strategies to climatic variability: A case study of small-scale farmers in rural Mexico", *Land Use Policy,* Vol. 38, pp. 533–540.

Centre for Indigenous Environmental Resources-CIER (2008), "*Climate change and First Nations South of 60: Impacts, adaptation, and priorities*" Report

Submitted to the Indian and Northern Affairs: Centre for Indigenous Environmental Resources Inc., Manitoba.

Chen, J., Wu, X., Finlayson, B. L., Webber, M., Wei, T., Li, M. and Chen, Z. (2014), "Variability and trend in the hydrology of the Yangtze River, China: Annual precipitation and runoff", *Journal of Hydrology,* Vol. 513, pp. 403–412.

Chijioke, O. B., Haile, M. and Waschkeit, C. (2011*), "Implication of climate change on crop yield and food accessibility in sub-Saharan Africa*", An inter-disciplinary term paper, Center for Development Research, University of Bonn.

Christensen J. H, Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Koli, R. K., Kwon, W. T., Laprise, R., Rueda, V. M., Mearns, L., Menendez, C. G., Raisanen, J., Rinke, A., Sarr, A. and Wheton, P. (2007), *"Regional climate projections*", In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (Eds), Climate change 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 847–940.

Cinco, T. A., Guzman, R. G., Hilario, F. D. and Wilson, D. M. (2014), "Long-term trends and extremes in observed daily precipitation and near surface air temperature in the Philippines for the period 1951–2010", *Atmospheric Research,* Vol. 145, No.146, pp.12–26.

Codjoe, S. N. A. and Owusu, G. (2011), "Climate change/variability and food systems: evidence from the Afram Plains, Ghana", *Regional Environmental Change,* Vol. 11, No. 4, pp. 1-13

Creswell, J. W. (2012), *Qualitative Inquiry and Research Design: Choosing Among Five Traditions* (3rd ed.): Sage Publications, Thousand Oaks, CA.

Creswell, J. W. (2010), *Research Design: Qualitative, Quantitative, and Mixed Methods Approach* (3rd ed.): Sage Publications, Thousand Oaks, CA.

Creswell, J. W. and Clark, V. L. P. (2010), *Designing and Conducting Mixed Methods Research*: Sage Publications, Thousand Oaks, CA.

Datta, S. (2013), "Impact of climate change in Indian Horticulture - A review", *International Journal of Science, Environment and Technology*, Vol 2, No. 4, pp. 661– 671.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. and Yesuf, M. (2009), "Determinants of farmers‟ choice of adaptation methods to climate change in the Nile Basin of Ethiopia", *Global Environmental Change*, Vol. 19, pp. 248255.

Deressa, T. T., Hassan, R. M. and Poonyth, D. (2005), “Measuring the impact of climate change on South African agriculture: the case of sugarcane growing regions”, *Agrekon*, Vol. 44, No. 4, pp. 542-524.

Deressa, T. T. and Hassan, R. M. (2007), “Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures”, *Journal of African Economies,* Vol. 18, No. 4, pp. 529–554.

Deuter, P. (2008), "Defining the impacts of climate change on horticulture in Australia", Report prepared for the Garnaut Climate Change Review, Canberra.

Dey, I, (1993), *Qualitative Data Analysis: A User Friendly Guide for Social Scientists*, Routledge, London.

Dontwi, J., Dontwi, I. K. and Buabeng, S. N. (2008), “Climate change impacts on fisheries production”, In: Allotey, J. and Mensah, L. (eds). Ghana climate change impacts, vulnerability and adaptation assessments, under the Netherlands climate assistance programme: Environmental Protection Agency, Chapter 2, Accra, pp. 14-73.

Eakin, H., Benessaiah, K., Barrera, J. F., Cruz-Bello, G. M. and Morales, H. (2012), “Livelihoods and landscapes at the threshold of change: Disaster and resilience in a Chiapas coffee community”, *Regional. Environmental Change,* Vol. 22, pp. 223–235.

Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., Kirilenko, A., Orton, K., Soussana, J. F. and Schmidhuber, J. (2007), *“Food, fibre and forest products”*, In: Parry, M.L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., Hansen, C. E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 307–328.

Easterling, D. R., Karl, T. R., Gallo, K. P., Robinson, D. A., Trenberth, K. E. and Dai, A. (2000), “Observed climate variability and change of relevance to the biosphere”, *Journal of Geophysical Research*, Vol. 105, No. 15, pp. 20,10120,114.

Eisenack, K. and Stecker, R. (2011), “An Action Theory of Adaptation to Climate Change”, Earth System Governance, Working Paper No. 13, Earth System Governance Project, Lund and Amsterdam, July 2011, pp. 7-9.

Food and Agricultural Organisation (2007), *Climate Variability and Change: Adaptation to Drought in Bangladesh,* FAO, Rome.

Fussel, H. M. and Klein, R. J. T. (2002), “*Vulnerability and Adaptation Assessments to Climate Change: An Evolution of Conceptual Thinking”,* Paper presented at UNDP Expert Group Meeting, 17-19 June 2002, Havana, Cuba.

Garrett, K. A., Dobson, A. D. M., Kroschel, J., Natarajan, B., Orlandini, S., Tonnang, H. E. Z. and Valdivia, C. (2013), "The effects of climate variability and the color of weather time series on agricultural diseases and pests, and on decisions for their management", *Agricultural and Forest Meteorology*, Vol. 170, pp. 216–227.

Gbetibouo, G.A. (2009), "*Understanding farmers" perceptions and adaptations to climate change and variability: the case of the Limpopo Basin, South Africa",* International Food Policy Research Institute, Discussion Paper 00849, February.

Ghartey, W., Addo-Quaye, A., Odoi, F. N. A. and Agyei-Frimpong, K. (2012), *Intermediate Agriculture I: Post Diploma in Basic Education Course Book*, University Printing Press, Center for Continuing Education, University of Cape Coast, pp. 142-143.

Gomez, B. and Jones, J. P. (2010), *Research methods in Geography*, John Wiley and Sons Ltd, Chichester, West Sussex.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. and Wiltshire, A. (2010), "Implications of climate change for agricultural productivity in the early twenty-first century", *Philosophical Transaction Royal Society Lond B. Biological Sciences,* Vol. 365, pp. 2973–2989.

Hansen, J. E., Ruedy, R., Sato, M. and Lo, K. (2012), "*NASA GISS surface temperature (GISTEMP) analysis, in trends: A compendium of data on global change",* Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

Hassan, R. and Nhemachena, C. (2008), "Determinants of African farmers" strategies for adapting to climate change: Multinomial choice analysis", *AfJARE*, Vol. 2, No 1, pp. 83-104.

Hatfield, J. L. and Prueger, J. H. (2011), "Spatial and temporal variation in evapotranspiration", In Gerosa, G. (ed.) Evapotranspiration - from measurements to agricultural and environmental applications, InTech, pp. 410.

Hisali, E., Birungi, P. and Buyinza, F. (2011), "Adaptation to climate change in Uganda: Evidence from micro level data", *Global Environmental Change*, Vol. 21, pp. 1245–1261.

Horna, D., Smale, M. and Falck-Zepeda, J. (2006), "Assessing the potential economic impact of genetically modified crops in Ghana: Tomato, garden egg, cabbage and cassava", *PBS report*, pp. 3-20.

Houghton, J., Ding, Y., Griggs, D., Noguer, M. and Van der Linden, P. (2001), *"Climate Change 2001: The Scientific Basis"*, Published for the

Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, pp. 881.

IPCC, (2014), Summary for policymakers. In: Stocker, T. F., Qin, D., Plattner, G. K., Tignor,M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (Eds.), "*Climate change 2013: The Physical Science Basis",* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC, (2012), M*anaging the risks of extreme events and disasters to advance climate change adaptation*, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC, (2007a), *Climate Change 2007: Impacts, adaptation and vulnerability,* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC (2007b), Summary for policymakers, In Solomon, S. et al. (Eds.), "*Climate change 2007: The physical science basis",* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC, (2007c), Summary for policymakers In: "*Climate change 2007: Impacts, adaptation and vulnerability",* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, (Eds.), Cambridge University Press, Cambridge, pp. 7-22.

IPCC, (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, Cambridge University Press, Cambridge.

Isik, M. and Devadoss, S. (2006), "An analysis of the impact of climate change on crop yields and yield variability", *Applied Economics*, Vol. 38, No. 7, pp. 835-844.

Jidauna, G. G., Dabi, D. D. and Dia, R. Z. (2011), "The effect of climate change on agricultural activities in selected settlements in the Sudano-Sahelian Region of Nigeria", *Archives of Applied Science Research*, Vol. 3, No. 6, pp.154165.

Kalibbala, J. M. (2011), "The influence of organic manure on tomato growth in Rakai District Uganda", A research report submitted to the Department of Zoology, In partial fulfillment of the requirement for the degree of Bachelor of Science, Makerere University.

Kassahun, M. M. (2009), “Climate change and crop agriculture in Nile Basin of Ethiopia: Measuring impacts and adaptation options”, A thesis submitted to the School of Graduate Studies, In partial fulfillment of the requirements for the degree of Master of Science, Addis Ababa University.

Kassie, B. T., Van Ittersuma, M. K., Hengsdijkb, H., Assengc, S., Wolfa, J. and Rötterda R. P. (2014), “Climate-induced yield variability and yield gaps of maize (Zea mays L.) in the Central Rift Valley of Ethiopia”, *Field Crops Research*, Vol. 160, pp. 41–53.

Kelley, W. T. and Boyhan, G. (2010), *Commercial Tomato Production handbook: History, Significance, Classification and Growth*, University of Georgia Cooperative Extension, Georgia.

Kemausuor, F., Dwamena, E., Bart-Plange, A. and Kyei-Baffour, N. (2011), “Farmers‟ perception of climate change in the Ejura-Sekyedumase District of Ghana”, *ARPN Journal of Agricultural and Biological Science*, Vol. 6, No.10, pp. 26-37.

Komba, C. and Muchapondwa, E. (2012), “Adaptation to climate change by smallholder farmers in Tanzania”, Economic Research Southern Africa (ERSA) working paper 299, Environmental-Economics Policy Research Unit (EPRU), School of Economics, University of Cape Town, Rondebosch, May, 10, pp. 5.

Kotake-Nara, E., Kushiro, M., Zhang, H., Sugawara, T., Miyashita, K. and Nagao, A. (2001), “Carotenoids affect proliferation of human prostate cancer cells”, *Journal of Nutrition*. Vol. 131, pp. 3303–3306.

Kotir, J. H. (2011), „Climate change and variability in sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security‟, *Environment, Development and Sustainability*, Vol. 13, No. 3, pp. 587–605.

Kruger, A. C. and Shongwe, S. (2004), “Temperature trends in South Africa: 1960–2003”, *International Journal of Climatology*, Vol. 25, No.15, pp.1929–1945.

Lee, J., Nadolnyak, D. and Hartarska, V. (2012), *“Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study”*, Department of Agricultural Economics and Rural Sociology, University of Auburn, Auburn.

Li, C., Ting, Z. and Rasaily, R. G.(2010), „Farmer‟s adaptation to climate risk in the context of China: A research on Jianghan plain of Yangtze River Basin‟, *Agriculture and Agricultural Science Procedia*, Vol. 1, pp. 116–25.

Lionello, P., Cavaleri, L., Nissen, K.M., Pino, C., Raicich, F. and Ulbrich, U. (2011), "Severe marine storms in the northern Adriatic: characteristics and trends", *Physics and Chemistry of the Earth*, Vol. 40, pp. 93-105.

Liu, S., Mo, X., Lin, Z., Xu, Y., Ji, J., Wen, G. and Richey, J. (2010), „Crop yield responses to climate change in the Huang-Huai-Hai Plain of China", *Agricultural Water Management*, Vol. 97, No. 8, pp. 1195-1209.

Lobell, D. (2010), "Crop responses to climate: Time-series models, in Climate Change and Food Security", Springer, Dordrecht, pp. 85-98.

Maddison, D. (2007), *"The perception of /and adaptation to climate change in Africa",* World Bank Policy Research Working Paper No. 4308.

Malla, G. (2008), "Climate change and its impact on Nepalese agriculture", *The Journal of Agriculture and Environment,* Vol. 9, No. 14, pp. 62-71.

Manyatsi, A. M., Mhazo, N. and Masarirambi, M. T. (2010), "Climate variability and change as perceived by rural communities in Swaziland", *Research Journal of Environmental and Earth Sciences*, Vol. 2, No. 3, pp. 164-169.

Manyeruke, C., Hamauswa, S. and Mhandara, L. (2013), "The effects of climate change and variability on food security in Zimbabwe: A socio-economic and political analysis", *International Journal of Humanities and Social Science,* Vol. 3, No. 6, pp. 207-286.

Mary, A. L. and Majule, A. E. (2009), "Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania", *African Journal of Environmental Science and Technology,* Vol. 3, No. 8, pp. 206-218.

Masahumi, J., Masayuki, O., Toru, M. and Yutaka, S. (2011), *"Crop Production and Global Warming, Global Warming Impacts - Case Studies on the Economy, Human Health, and on Urban and Natural Environments"*, Stefano Casalegno (Ed.), InTech, Available from: http://www.intechopen.com/books/global-warming-impacts-case-studies-onthe-economy-human-health-andon-urban-and-natural-environments/cropproduction-and-global-warming, pp. 139-152. Accessed on the 21st April, 2014.

McLeman, R. A. and Hunter, L. M. (2010), "Migration in the context of vulnerability and adaptation to climate change: insights from analogues", *Wiley Interdisciplinary Review of Climate Change*, Vol. 1, No.3, pp. 450–461.

McLeman R. A. and Smit, B. (2006),"Migration as an adaptation to climate change", *Climate Change,* Vol. 76, pp. 5-31.

McSweeney, C., New, M. and Lizcano, G. (2008), "UNDP Climate Change Country

Profiles: Ghana", School of Geography and Environment, University of Oxford, Oxford, United Kingdom. Available from: http://country profiles.geog.ox.ac.uk; accessed April 2011.

Mengistu, D. K. (2011), "Farmers‟ perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray, Ethiopia", *Agricultural Science*, Vol.2, No. 2, pp. 138-145.

Mensah, G. S., Kwarteng, E. N. and Baffour-Antwi, A. K. (2013), *General Agriculture For Senior High Schools*, Adwinsa Publication (Gh) Ltd, Accra.

Minia, Z. (2008), "Climate change scenario development", *In* Agyemang-Bonsu, W. K. (Ed): Ghana Climate Change Impacts, Vulnerability and Adaptation Assessments, Environmental Protection Agency, Accra, Ghana, pp. 2-13.

Mitchell, W., Chittleborough J., Ronai, B. and Lennon G. W. (2000), "Sea level rise in Australia and the Pacific", *Climate Change Newsletter*, Vol. 12, pp. 7–10.

MoFA, (2010), *Agriculture in Ghana*: *Facts and* Figures, Accra, Ministry of Food and Agriculture Statistics, Research and Information Directorate (SRID).

MoFA, (2014), *Offinso North District Annual Production Report*, Offinso North District, MoFA.

Molua, E. and Lambi, C. (2006), "The economic impact of climate change on agriculture in Cameroon", CEEPA Discussion Paper No. 17. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Morton, J. F. (2007), "The impact of climate change on smallholder and subsistence agriculture", *Proceedings of the National Academy of Sciences*, Vol. 104, No. 50, pp.19680-19685.

Mubaya, C. P., Njuki, J., Liwenga, E., Mutsvangwa, E. P. and Mugabe, F. T. (2010), "Perceived impacts of climate related parameters on smallholder farmers in Zambia and Zimbabwe", *Journal of Sustainable Development in Africa*, Vol. 12, No.5, pp.170-186.

Mudombi, G. (2011), "Factors affecting perceptions and responsiveness to climate variability induced hazards", A thesis submitted to the Department of Agricultural Economics and Extension, Faculty of Agriculture, University of Zimbabwe, pp. 8-14.

NAAS, (2013), "*Climate Resilient Agriculture in India"*, Policy Paper No. 65, National Academy of Agricultural Sciences, New Delhi: pp.20.

Naika, S., de Jeude. V. L., de Goffau, D., Hilm, M. and van Dam, B. (2005), "Cultivation of Tomato: Production, Processing and Marketting", Agrodok 17, Dififrafi, Wageningen, Netherlands, pp. 1-10.

Naeve, S. (2002), "Flooded Field and Soybean Survival", Minnesota Crop eNews, July 14, University of Minnesota. (http://www.extension.umn.edu/crop Enews/2002/02MNCN26.htm), Assessed on 15th May, 2014.

Nhemachena, C. and R. Hassan, (2007), *"Micro-Level Analysis of Farmers" Adaptation to Climate Change in Southern Africa"*, IFPRI Discussion Paper No. 714, Washington, DC, International Food Policy Research Institute.

Offinso North District Assembly [ONDA] (2013), *Update of Socio-Economic Profile of the District*, Offinso-North, *ONDA.*

Offinso North District Assembly [ONDA] (2012), *Update of Socio-Economic Profile of the District*, Offinso-North, *ONDA.*

Offinso North District Assembly [ONDA] (2011), *Update of Socio-Economic Profile of the District*, Offinso-North, *ONDA.*

Offinso North District Assembly [ONDA] (2010), *Update of Socio-Economic Profile of the District*, Offinso-North, *ONDA.*

Ogalleh, S. A., Vogl, C. R., Eitzinger, J. and Hauser, M. (2012), "Local perceptions and responses to climate change and variability: The case of Laikipia District, Kenya", *Sustainability*, Vol. 4, pp. 3302-3325.

Owombo, P. T., Koledoye, G. F., Ogunjimi, S. I., Akinola, A. A., Deji, O. F. and Bolarinwa, O. (2014), "Farmers" adaptation to climate change in Ondo State, Nigeria: A gender analysis", *Journal of Geography and Regional Planning*, Vol. 7, No. 2, pp. 30-35.

Oxfam, (2011), *Briefing on the Horn of Africa Drought: Climate Change and Future Impacts on Food Security*, Oxfam, New Zealand, pp. 1-5.

Pallant, J. (2001), *SPSS Surviving Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows Version 12*, Allen and Unwin, Sidney.

Pangapanga, P. I., Jumbe, C. B., Kanyanda, S. and Thangalimodzi, L. (2011), "Unraveling strategic choices towards droughts and floods" adaptation in Southern Malawi", *International Journal of Disaster Risk Reduction*, Vol. 2, pp. 57–66.

Peña, R. and Hughes, J. (2007), "Improving vegetable productivity in a variable and changing climate", *SAT eJournal*, Vol. 4, No.1, pp. 10.

Petrie, M. D., Collins, S. L., Gutzler, D. S. and Moore, D. M.(2014), "Regional trends and local variability in monsoon precipitation in the northern Chihuahuan Desert, USA", *Journal of Arid Environments*, Vol. 103, pp. 63-70

Pinto, D. A., Demirag, U., Haruna, A., Koo, J. and Asamoah, M. (2012), "*Climate Change, Agriculture, and Food crop Production in Ghana",* International Food Policy Research Institute (IFPRI), Accra.

Poulter, B., Pederson, N., Liu, H., Zhu, Z., D"Arrigo, R., Ciais, P., Davi, N., Frank, D., Leland, C., Myneni, R., Piao, S. and Wang, T. (2013), "Recent trends in Inner Asian forest dynamics to temperature and precipitation indicate high sensitivity to climate change", *Agricultural and Forest Meteorology*, Vol. 178, No.179, pp. 31–45.

Raman, V. V. S., Iniyan, S. and Goic, R. (2011), "A review of climate change, mitigation and adaptation", *Renewable and Sustainable Energy Reviews*, Vol. 16, No. 1, pp. 878-897.

Reidsma, P., Ewert, F., Lansink, A. O. and Leemans, R. (2010), "Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses", *European. Journal Agronomy,* Vol. 32, pp. 91–102.

Robinson, J. Z. E. and Kolavalli, L. S. (2010), "The Case of Tomato in Ghana: Productivity", Ghana Strategy Support Program (GSSP) Working Paper No. 19, Development and Strategy Governance Division, IFPRI, Ghana, 23 April, pp. 1-19.

Rodriguez-Solorzano, C. (2014), "Unintended outcomes of farmers" adaptation to climate variability: deforestation and conservation in Calakmul and Maya biosphere reserves", *Ecology and Society,* Vol. 19, No. 2, pp. 2.

Romain, R. H. (2011), "Crop Production in Tropical Africa", Goekint Graphics, Nv. Belgium, pp. 467-475.

Roudier, P., Sultan, B., Quirion, P. and Berg, A. (2011), "The impact of future climate change on West African crop yields: What does the recent literature say?", *Global Environmental Change*, Vol. 21, No. 3, pp. 1073-1083

SAGUN, (2009), "*Climate Change Impacts on Livelihoods of Poor and Vulnerable Communities and Biodiversity Conservation: A Case Study in Banke, Bardia, Dhading and Rasuwa District of Nepal",* Strengthened Actions for Governance in Utilization of Natural Resources Program, CARE Nepal, Kathmandu, Nepal, pp. 56.

Sarker, A. R. (2012), "Impacts of climate change on rice production and farmers" adaptation in Bangladesh", A dissertation submitted in fulfillment of the requirements for the degree of Doctor of Philosophy, School of Accounting, Economics and Finance, University of Southern Queensland.

Sarr, O. (2010), "Adapt or Die: A Climate Change for African Cities", The Ghanaian Spectator, Saturday, October 30, pp. 28.

Sayemuzzaman, M., Jha, M. K., Mekonnen, A. and Schimmel, K. A. (2014), "Subseasonal climate variability for North Carolina, United States", *Atmospheric Research,* Vol. 145–146, pp. 69–79.

Schlenker, W. and Lobell, D. B. (2010), "Robust negative impacts of climate change on African agriculture", *Environmental Research Letters,* Vol. 5, pp.1-8.

Sinnadurai, S. (1992), *Vegetable Cultivation*, Asempa Publishers, Accra.

Smit, B. and Skinner, M. W. (2002), "Adaptation options in agriculture to climate change: A typology", *Mitigation and Adaptation Strategies for Global Change,* Vol.7, pp. 85–114.

Stanturf, J. A., Warren, M. L., Charnley, J. S., Polasky, S. C., Goodrick, S. L., Armah, F. and Nyako, Y. A. (2011), "Ghana Climate Change Vulnerability and Adaptation Assessment Report", June, 2011, USAID, Accra.

Sudarkodi, K. and Sathyabama, K. (2011), "The Impact of Climate Change on Agriculture", Munich Personal RePE Archive (MPRA), Paper No. 29784, April 2011, Available at, http://mpra.ub-muenchen.de, Assessed on 15th May, 2014.

Sumelius, J., Bäckman, S., Rötter, R. and Kahiluoto, H. (2009), "*General Theoretical Framework, the SARD-Climate Project",* University of Helsinki, Department of Economics and Management, Discussion Papers No. 30, USA.

Tampoare, G. B., Bob-Milliar, G. K. and Adazabra, N. (2012), "Analyzing the economic benefit of fresh tomato production at the Tono Irrigation Scheme in Upper East Region of Ghana", *Journal of Economics and Sustainable Development*, Vol. 3, No. 13, pp. 15-22.

Tao, H., Gemmer, M., Bai, Y., Su, B. and Mao, W. (2011), "Trends of stream flow in the Tarim River Basin during the past 50 years: Human impact or climate change?", *Journal of Hydrology,* Vol. 400, pp.1-9.

Teka, O. and Vogt, J. (2010), "Social perception of natural risks by local residents in developing countries – the example of the coastal area of Benin", *The Social Science Journal*, Vol. 47, pp. 215-224.

Third World Network-TWN (2007), *The history of tomato farming in Ghana,* Accra, Ghana Today, pp. 23-24.

Traore,B., Corbeels, M., Van Wijk, M. T., Rufino, M. C. and Giller, K. E. (2013), "Effects of climate variability and climate change on crop production in southern Mali", *European Journal of Agronomy,* Vol. 49, pp. 115–125.

Tshiala, M. F. and Olwoch, J. M. (2010), "Impact of climate variability on tomato production in Limpopo Province, South Africa", *African Journal of Agricultural Research*, Vol. 5, No. 21, pp. 2945-2951.

Tubiello, F. (2012), "*Climate Change Adaptation and Mitigation: Challenges and Opportunities in the Food Sector"*, Natural Resources Management and Environment Department, FAO, Rome.

Tunde, A. M. (2011), "Perception of climate variability on agriculture and food security by men and women farmers in Idanre L.G.A, Ondo State, Nigeria", *Ethiopian Journal of Environmental Studies and Management,* Vol. 4, No. 2. pp. 19-32.

Uddin, M. N., Bokelmann, W. and Entsminger, J. S. (2014), "Factors affecting farmers‟ adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh", *Climate,* Vol. 2, pp. 223241.

United Nations Framework Convention on Climate Change-UNFCCC, (2007), "*Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries"*, Bonn, Climate Change Secretariat, Development and Strategy Governance Division, IFPRI, Ghana Strategy Support Program (GSSP), Accra, Ghana, 19, pp. 1-9.

Valdivia, C., Jette´, C., Quiroz, R., Gilles, J. L. and Materer, S. (2002), "Peasant households‟ strategies in the Andes and potential users of climate forecasts: El Nino of 1997–1998", Selected paper for the Annual Meeting of the American Agricultural Economics Association, July 30–August 2, Tampa, FL. USA.

Vignola, R., Koellner, T., Scholz, R. W. and McDaniels, T. L. (2010), "Decisionmaking by farmers regarding ecosystem services: factors affecting soil conservation efforts in Costa Rica", *Land Use Policy,* Vol. 27, pp. 11321142.

Waithaka, M., Nelson, G. C., Thomas, T. S. and Kyotalimye, M. (2013), *Eastern African agriculture and climate change: A comprehensive analysis,* International Food Policy Research institute, Washington.

Walker, B. and Salt, D. (2006), *Resilience thinking: Sustaining ecosystems and people in a changing world,* Island Press, USA.

Walthall, C. L., Hatfield, P.,Backlund, L., Lengnick, E., Marshall, M., Walsh, M., Adkins, S., Aillery, M., Ainsworth, E. A., Ammann, C., Anderson, C. J., Bartomeus, I., Baumgard, L. H., Booker, F., Bradley, B., Blumenthal, D. M., Bunce, J., Burkey, K., Dabney, S. M., Delgado, J. A., Dukes, J., Funk, A., Garrett, K., Glenn, M., Grantz, D. A., Goodrich, D., Hu, S., Izaurralde, R. C., Jones, R. A. C., Kim, S. H., Leaky, A. D. B., Lewers, K., Mader, T. L., McClung, A., Morgan, J., Muth, D. J., Nearing, M., Oosterhuis, D. M., Ort, D., Parmesan, C., Pettigrew, W. T., Polley, W., Rader, R., Rice, C., Rivington, M., Rosskopf, E., Salas, W.A., Sollenberger, L.E., Srygley, R., Stöckle, C., Takle, E. S., Timlin, D., White, J. W., Winfree, R., WrightMorton, L. and Ziska, L.H. (2012), *Climate change and agriculture in the United States: Effects and adaptation*, USDA Technical Bulletin, Washington, DC.

Welch, J. R., Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A. and Dawe, D. (2010), "Rice yields in tropical/ subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures", *Proceedings of the National Academy of Science*, Vol. 107, No. 33, pp. 14562–14567.

Williams, A (2003), "How to write and analyse a questionnaire", *Journal of Orthodontics*, Vol. 30, No. 3, pp. 245-252.

World Bank, (2009), "*Awakening African"s sleeping giants: Prospects for commercial agriculture in the Guinea Savannah Zone and beyond",* Bank for Reconstruction and Development / World Bank.

Zorom, M., Barbier, B., Mertz, O. and Servat, E. (2013), "Diversification and adaptation strategies to climate variability: A farm typology for the Sahel", *Agricultural Systems,* Vol. 116, pp. 7–15.

APPENDICES

APPENDIX ONE

STRUCTURED INTERVIEW GUIDE FOR TOMATO FARMERS

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF TOMATO FARMERS

No.	Questions	Response
1	Gender	1. Male [ ] 2. Female [ ]
2	Age	1. 10-19 year [ ] 2. 20-30 years [ ] 3. 31-40years [ ] 4. 41-50years [ ] 5. 51years up [ ]
3	Marital status	1. Married [ ] 2. Single [ ] 3. Widow/Widower [ ] 4. Divorced [ ]
4	Number of years lived in the community	1. 10-20 years [ ] 2. 21-30 years [ ] 3. 31- 40years [ ] 4. 41years and above [ ]
5	Number of years into tomato cultivation	1. 10-20 years [ ] 2. 21-30 years [ ] 3. 31- 40years [ ] 4. 41years and above [ ]
6	Average seasonal income	1. Below GH¢100 [ ] 2. GH¢100 -200 [ ] 3. GH¢210-300 [ ] 4. GH¢ 310-400 [ ] 5. GH¢ 410-500 [ ] 6. Above GH¢ 500 [ ]
7	How will you describe your seasonal income?	1. Regular [ ] 2. Not regular [ ]
8	What is the state of your income for the past decade?	1. Increasing [ ] 2. Decreasing [ ] 3. Constant [ ]

9	How much do you spend on these items monthly	
		Items
	Total monthly expenditure	Food and water

	GH¢…………………………………… Total seasonal expenditure GH¢…………………………………… All expenses on the listed items plus all other expenses should add up to the total monthly expenditure.	Labour Transportation Farm tools (Cutlass, hoe, watering cann etc. Seeds and Seedlings Agro-chemicals (fertiliser, ammonia, furadan etc.) Health care (*Orthodox & Herbal)* All other expenses
10	Have you had formal education?	1. Yes [ ] 2. No [ ]
11	What is the highest level of education	1. Primary school [ ] 2. Middle school [ ] 3. Secondary[ ] 4. Tertiary [ ]
12	What is the size of your Farmland	1. 1-3 acres [ ] 2. 4-6acres [ ] 3. 7-9 acres [ ] 4. 10 acres and above [ ]
13	Do you get access to credit facility	1. Yes [ ] 2. No [ ]
14	Where do you get these credit facilities from	1. Credit Unions [ ] 2. Cooperative society [ ] 3. Commercial Banks [ ] 4. Rural Banks [ ] 5. Government institutions (e.g. MoFA) [ ] Others, specify…………………………

SECTION B: THE TREND OF CLIMATE VARIABILITY IN THE DISTRICT

15 Have you observed any variability of the 1. Yes [ ] climate over the past decade? 2. No [ ]
3. No idea [ ]

16 Which of the climate variables have 1. Temperature [ ] varied over the past decade 2. Rainfall [ ]
3. Others, specify ……………………

17 How has the variability in climate 1. Protracted drought[ ] manifested in your observation 2. Unpredictable rainfall pattern[ ]
3. Heavy rainfall [ ]
4. High Temperatures [ ]
5. Strong winds [ ]
6. Others, specify……………………

18 What has been the rainfall pattern in this community for the past ten years in terms of intensity, quantity and timing?

Intensity	High [ ]	Low [ ]
Quantity	High [ ]	Low [ ]
Timing	Right time [ ]	Delay [ ]

19 To what extent has the climate been 1. Severe [ ] warming over the last decade? 2. Moderate [ ]
3. Not at all [ ]

20 Have you experienced any drought 1. Yes [ ] condition over the last 10 years? 2. No [ ]
3. No idea [ ]

21 If yes, how do you describe the drought condition in this community in terms of severity and longevity?

Severity	Highly	Moderately	Low
Longevity	Very long	Moderate	Short

22 Have you ever experienced any flooding 1. Yes [ ] in your farm? 2. No [ ]
3. No idea [ ]

23 If yes, how frequent is it on your farm? 1. Yearly [ ]
2. Quarterly [ ]
3. Annually [ ]
4. Seasonally [ ]

24 How do you foresee future warming 1. More warming [ ] condition of this district? 2. Low warming [ ]

3. No warming [ ]

25 Do you receive information or data from the weather station

1. Yes [ ] 2. No [ ]

SECTION C. EFFECTS OF TEMPERATURE ON TOMATO PRODUCTION

26	Which of the following varieties of tomato do you cultivate?	1. Power [ ] 2. Raster[ ] 3. Power Rano [ ] 4. Wosowoso [ ] 5. Royal [ ] 6. Pectomech [ ] 7. Burkina [ ] 8. Roma [ ] 9. Others, specify…………………………
27	Why do you cultivate the type of variety in Q26	
28	What is the nature of the soil you cultivate?	Loam [ ] Sandy loam [ ] Sandy [ ]
29	Is there any significant relationship between temperature and tomato production	1. Yes [ ] 2. No [ ] 3. No idea [ ]
30	If yes, which type of relationship exist	1. Positive [ ] 2. Negative [ ]
31	Does high temperature affect tomato yield?	1. Yes [ ] 2. No [ ]
32	If yes, what is the degree of effect? **NB. Tick the appropriate one**	Increase / Decrease / No effect
33	Which type of variety is highly affected by high temperature in the options in Q25?	
34	Does high temperature affect tomato availability?	1. Yes [ ] 2. No [ ]
35	To what extent does it affect tomato availability?	Increase / Decrease / No effect

SECTION D. EFFECT OF RAINFALL VARIABILITY ON TOMATO PRODUCTION

36	Is there any possible relationship between rainfall and tomato production	1. Yes [ ] 2. No [ ]
37	If yes, which type of relationship exist	1. Positive [ ] 2. Negative [ ]
38	Does rainfall variability affect tomato yield?	1. Yes [ ] 2. No [ ]
39	If yes, what is the degree of effect?	Increase / Decrease / No effect

40	Which type of variety is highly affected by rainfall variability in the options in Q25?	
41	Does rainfall variability affect tomato availability?	1. Yes [ ] 2. No [ ]
42	To what extent does it affect tomato availability?	Increase / Decrease / No effect
43	Do you only rely on rainfall for the cultivation of tomato during the rainy season?	1. Yes [ ] 2. No [ ]
44	If no, identify some of the methods you adopt	

SECTION E. EFFECT OF EXTREME CLIMATIC EVENT ONTOMATO PRODUCTION

45	Have you observed any extreme climatic event in your locality for the past decade?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
46	If yes what kind of climatic event have you observed during this period	1. Flood [ ] 2. Drought [ ] 3. Strong winds [ ]
47	In your opinion, does the extreme climatic event have any effect on tomato cultivation?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
48	If yes at what point of production does it affect	1. Land preparation [ ] 2. Flower development [ ] 3. Fruit development [ ] 4. Ripe period [ ]
49	To what extent do floods affect tomato production	Increase / Decrease / No effect
50	To what extent do drought affect tomato production	Increase / Decrease / No effect

SECTION F. PERCEPTIONS OF THE EFFECTS OF CLIMATE VARIABILITY ON TOMATO PRODUCTION

51	How do you perceive climate variability to be?	1. Changes in temperature Yes [ ] No [ ] 2. Changes in rainfall pattern Yes [ ] No [ ] 3. Changes in solar radiation Yes [ ] No [ ] 4. Frequency of flooding Yes [ ] No [ ] 5. Frequency of drought Yes [ ] No [ ] Others, specify……………………………
52	What is the level of your knowledge of climate variability and climate change?	1. Very good [ ] 2. Good [ ] 3. Very poor [ ] 4. Poor [ ] 5. Don"t know [ ]
53	How do you perceive the effect of climate variability on agriculture?	1. Inadequate food supply Yes [ ] No [ ]
		2. Poor crop yields Yes [ ] No [ ] 3. Incidence of crop diseases Yes [ ] No [ ] 4. Death of livestock Yes [ ] No [ ]
54	Do you think the climate is changing at a rate that is significantly affecting tomato availability?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
55	Do you think the climate is changing at a rate that is significantly affecting tomato accessibility?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
56	If yes, how?	
57	Do you think the climate is changing at a rate that is significantly affecting tomato nutritional value?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
58	Do you harvest the same quantity of crop yield now as compared to the past number of years?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
59	What is the trend of the quantity of crop yield	1. Increase [ ] 2. Decrease [ ]
60	If your yield decreases, what might possibly be the cause for that?	
61	What human factors are responsible for climate variability in your locality?	1. Vehicular emissions of fumes Yes [ ] No [ ] 2. Deforestation Yes [ ] No [ ] 3. Slash and burn Yes [ ] No [ ] 4. Bush burning Yes [ ] No [ ] 5. Industrial emissions Yes [ ] No [ ] 6. Fertiliser application Yes [ ] No [ ]
62	Do you apply agro-chemicals?	1. Yes [ ] 2. No [ ]

63	What type of fertiliser do you use? Why?	
64	Apart from human factors, what other factors cause climate variability?	1. Natural processes [ ] 2. Spiritual factors [ ] 3. Don‟t know [ ] Specify, if any

SECTION G. ADAPTATION TO CLIMATE VARIABILITY IMPACT

65	Which of the following on-farm adaptation options do you adopt in the event of crop failure due to the changing climate?	1. Crop diversification Yes [ ] No [ ] 2. Use of agrochemicals Yes [ ] No [ ] 3. Mixed cropping Yes [ ] No [ ] 4. Changing crop varieties Yes [ ] No [ ] 5. Irrigation farming Yes [ ] No [ ] 6. Changes in farm location Yes [ ] No [ ]
66	Which of the following off-farm adaptation options do you adopt in the event of crop failure due to the changing climate?	1. Diversification to non-farm activities Yes [ ] No [ ] 2. Migration Yes [ ] No [ ] 3. Non-adaptation Yes [ ] No [ ]
67	Which non-farm activities do you	1. Trading Yes [ ] No [ ]

	engage in apart from the farming activity	2. Dress making Yes [ ] No [ ] 3. Fashion designing and beauticians Yes [ ] No [ ] 4. Carving Yes [ ] No [ ] 5. Rearing of farm animals Yes [ ] No [ ] Specify, if any
68	What necessitate the selection of your choice of adaptation?	1. Community-based governance system[ ] 2. Age [ ] 3. Availability of resources e.g. finance [ ] 4. Land tenure status [ ] 5. Education [ ] 6. Experience [ ] 7. Extension services [ ] Others, specify…………………
69	What is the degree of effectiveness of the various adaptation practices you employ?	1. Very effective [ ] 2. Moderately effective [ ] 3. Not effective [ ]
70	Do the following affect your ability to adapt to the varying climate?	

	Yes	No
1. Lack of knowledge on the situation		

		2. Constrains to expand farm size due to limited land		
		3. High cost of agricultural inputs		
		4. Lack of access to climate data		
		5.Lack of access to water		
		6. Financial constraint		
		Other, specify		

71	Which of the following do you practice?	1. Irrigation farming [ ] 2. Non irrigation farming [ ]
72	Why are you not employing irrigation	1. It is costly 2. It is tedious 3. Just don"t like it
73	Do you receive support (e.g. extension services, finance etc.) from the government	1. Yes [ ] 2. No [ ] 3. No idea [ ]
74	Do you receive any form of training from any institution in the district to help your adaptive capacity	1. Yes [ ] 2. No [ ] 3. No idea [ ]
75	If yes, what kind of training do you receive?	
76	What kind of government support do you receive to help you adapt to	1. Extension services [ ] 2. Finance [ ]
	the varying climate to boost your production	3. Agro-chemicals [ ] 4. Farming tools and equipment [ ] Other, specify……………
77	What is the impact of these support systems on your production?	1. Increase yield [ ] 2. Decrease yield [ ] 3. Constant yield [ ]
78	Apart from the climate, what other challenges affect tomato farmers in the district	

APPENDIX TWO

Interview guide for meteorological attendant (Akomadan weather station)

1. Are you aware of climate variability in the district?
2. In your opinion, have you observed any variability in temperature for the past two decades in the district?
3. In your opinion have you observed any variability in rainfall pattern for the past two decades in the district?
4. In your view, have the district experienced extreme climatic events over the years?
5. How are these climatic variations manifested in the district?
6. What is the frequency of your observations to these manifestations?
7. How do you project future warming conditions in the district?
8. How do you foresee future rainfall pattern in the district?
9. In your opinion, what may be some of the possible causes of these climatic variations?
10. In your view, what may be some of the potential effects of these climatic variations on crops
11. Are farmers aware of the weather station and the relevance of its existence in the district?
12. Does your office inform or educate farmers about the climatic conditions of the district and their implications? Yes [ ] No [ ]. If yes, how do you do that?

APPENDIX THREE

Interview guide for key informant (Official of MoFA)

1. Are you aware of climate variability in the district?
2. Have you observed any variability in temperature for the past two decades?
3. In your opinion, have you observed any variability in rainfall pattern in the district for the past two decades?
4. How does this variability in climate manifest themselves in this community?
5. How frequent have you observed this/these manifestation(s)
6. In your own opinion, what have been the trend in temperature over the past years
7. In your own opinion, what have been the trend in rainfall pattern over the past years
8. In your own opinion, how does temperature variability affect tomato production?
9. In your own opinion, how does rainfall variability affect tomato production?
10. In your opinion, how has extreme climatic events (e.g. drought, flood etc.) affected tomato production in the district?
11. Is there any positive effect of temperature variability on tomato production? Yes [ ] No [ ]. If yes what are some of these effects?
12. Is there any positive effect of rainfall variability on tomato production? Yes [ ] No [ ]. If yes what are some of these effects?
13. In your own opinion, has climate variability affected the livelihood of farmers in the district? Yes [ ] No [ ]. If yes how?
14. Do you provide any assistance to farmers in times of crop failure due to extreme climatic conditions?
15. How does your office help farmers in their attempt to responding to the variability in climate?
16. Does your office provide any training programmes to farmers to enhance their adaptive capacity in response to climate variability? Yes [ ] No [ ]. If yes how?
17. What is the effectiveness of your training to improving farmers" adaptive capacities?
18. What are some of the challenges you encounter in your training activities with the farmers?
19. What are some of the possible measures your office is putting in place to solve these challenges?

APPENDIX FOUR

Interview guide for key informant (Official of Crops Research Institute of Ghana)

1. Are you aware of climate variability in the district?
2. Have you observed any variability in temperature for the past two decades?
3. In your opinion, have you observed any variability in rainfall pattern in the district for the past two decades?
4. How do these variability in climate manifest themselves in this community?
5. How frequent have you observed this/these manifestation(s)
6. In your own opinion, what have been the trend in temperature over the past years
7. In your own opinion, what have been the trend in rainfall pattern over the past years
8. In your own opinion, how does temperature variability affect tomato production?
9. In your own opinion, how does rainfall variability affect tomato production?
10. In your opinion, how has extreme climatic events (e.g. drought, flood etc.) affected tomato production in the district?
11. Is there any positive effect of temperature variability on tomato production? Yes [ ] No [ ]. If yes what are some of these effects?
12. Is there any positive effect of rainfall variability on tomato production? Yes [ ] No [ ]. If yes what are some of these effects?
13. In your own opinion, has climate variability affected the livelihood of farmers in the district? Yes [ ] No [s]. If yes how? …………
14. Do you provide any assistance to farmers in times of crop failure due to extreme climatic conditions?
15. How does your office help farmers in their attempt to responding to the variability in climate?

APPENDIX FOUR

RESULTS OF MULTIPLE (HIERARCHICAL) REGRESSION ANALYSIS

Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.477[a]	.228	.083	790.581	.228	1.571	3	16	.235
2	.853[b]	.728	.631	501.295	.501	12.897	2	14	.001

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2945166.380	3	981722.127	1.571	.235
	Residual	1.000E7	16	625018.211		
	Total	1.295E7	19			
2	Regression	9427308.095	5	1885461.619	7.503	.001
	Residual	3518149.655	14	251296.404		
	Total	1.295E7	19			

Coefficients

		Unstandardised Coefficients		Standardised Coefficients			Correlations			Collinearity Statistics	
	Model	B	Std. Error	Beta	T	Sig.	seroorder	Partial	Part	Tolerance	VIF
1	(Constant)	17560.213	1815.422		9.673	.000					
	Irrigation	844.399	829.701	.224	1.018	.324	.209	.247	.224	.998	1.002
	Tomato variety	353.662	236.795	.328	1.494	.155	.321	.350	.328	.998	1.002
	Regular weeding	710.604	570.490	.274	1.246	.231	.275	.297	.274	1.000	1.000
2	(Constant)	45144.637	5564.746		8.113	.000					
	Irrigation	1044.265	527.573	.277	1.979	.068	.209	.468	.276	.993	1.007
	Varieties of tomato	39.522	173.323	.037	.228	.823	.321	.061	.032	.749	1.335
	Regular weeding	237.713	459.618	.092	.517	.613	.275	.137	.072	.619	1.615
	Rainfall	-1.496	1.021	-.270	-1.465	.000	-.272	-.365	-.204	.572	1.747

Temperature	-924.148	182.408		-.788	-5.066	.000	-.741	-.804	-.706	.803	1.245