CLIMATE CHANGE AND FOOD CROP SECURITY IN GHANA: A CASE OF BIBIANI – AHWIASO – BEKWAI DISTRICT

By

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DECLARATION

I hereby declare that this thesis is my own work towards the Master of Philosophy Degree in Geography and Rural Development and that, it contains no material previously published by another person or materials which have been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to my dear mother Madam Mary Adjei, my sisters Margaret Mensah, Esther Mensah, Grace Mensah, Juliana Mensah and my brother Victor Stevenson Mensah. I say thank you very much for your prayers, encouragement and financial assistance. God bless you abundantly.

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ABSTRACT

Climate Change (CC) poses threat to food crop production especially in a developing country like Ghana. As a result, this study examined the impact of CC on output of maize, cassava and plantain in the Bibiani-Ahwiaso-Bekwai (BAB) district and farmers adaptation strategies. Questionnaires, focus group discussions, interview guide and direct observation were the main instruments used for gathering primary data from 231 households, selected randomly and purposively from six communities. Again, 31 years‟ time series data points from secondary sources were used to perform multiple regression analysis. Analysis was done using the Eviews software for Ordinary Least Squares (OLS), MAKESENS Excel template for Trend analysis, IBM SPSS version 20 for Cross tabulation, Microsoft Excel, 2013 for frequency charts and thematic analysis for all qualitative data analysis. The results of the study revealed that, changes (increase) in temperature has a significant negative impact (decrease) on output of maize. From farmers‟ perspective, negative impacts of CC on crops are greatly felt during fruits development and maturation stages in the production process. Again, some farming practices (like deforestation and slash and burn) apart from contributing to anthropogenic induced CC, also exacerbate the effects of CC on crops. Also, the quantity of output of crops is positively related to land area with high significance level. Finally, mixed cropping and mulching were mostly used by farmers to adapt to CC which were basically determined by farmers‟ years of farming experience and the fact that they were relatively cost effective. Unfortunately, institutional mitigation strategies were not functioning (were very weak) in the district. The study thus recommended that mitigation should be made „crop and stage specific‟ in the production process and experienced farmers should be involved in public education on best adaptation options. Communication and education about CC should also be intensified and made more meaningful to farmers if institutional mitigation strategies would be effective.

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LIST OF ABBREVIATION

BAB	Bibiani Ahwiaso Bekwai
BwN	Building with Nature
CA	Content Analysis
CC	Climate Change
CV	Coefficient of Variation
DPSIR	Driving forces-Pressure-State-Impact- Response
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMA	Ghana Meteorological Agency
GSS	Ghana Statistical Service
HLPE	High Level Panel of Experts on Food Security and Nutrition
IEA	Integrated Environmental Assessment
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
LA	Land Area
MoFA	Ministry of Food and Agriculture
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
SPSS	Statistical Package for the Social Sciences
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
W.F.P.	World Food Programme

CHAPTER ONE

BACKGROUND TO THE STUDY

1.1. INTRODUCTION

Climate change has attracted global attention than any other recent geographical phenomena. This is evidenced in the number of international committees and organisations about it and their various annual reports as well as its inclusion in academic discipline as a permanent field of study at degree levels of various higher institutions. It is considered the biggest environmental threat in human history and the defining human challenge for the twenty-first century (IPCC, 2001; UNDP, 2007). Global climate has indeed changed and is still changing - an observation and assertion made by Fellmann *et al*, (2005) that the structure of the ecosphere is not eternal and unchanging, rather alteration is the constant rule of the physical environment and would be so even in the absence of human and their distorting impacts. Consequences of such climate change are already felt throughout the Earth system and the effects thereof are observed on every continent and in all sectors. However, adaptation to these changes needs to not only respond to these impacts, but also needs to be integrated into sustainable development strategies and their implementation.

The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defined climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". To them climate change involves a change in climatic variables (such as rainfall, temperature and wind speed) which is caused by both anthropogenic and natural factors over longer time periods. The most mentioned climatic variables identified to have direct relationship with crop production and which affect output of various crops are temperature, precipitation and extreme weather events such as flood, windstorm and drought. Thus, climate change is considered as gradual but noticeable changes in regional or global-scale patterns of ancient climatic variables (particularly rainfall and temperature) induced by man or natural means which usually results in sporadic but progressively recurrent dangerous impacts.

There is rising anxiety about the effect of CC on human life, as the scientific agreement grows that significant climate change is very likely to occur over the 21st century (Christensen and Hewitson, 2007). As global climate keeps changing, there is need to worry and intensify research focus on it since various earth systems such as agriculture and soil are vulnerable to impacts accompanying such changes. In regards to agriculture, the general agreement is that changes in temperature and rainfall will result in changes in land and water regimes that will then disturb agricultural output (World Bank, 2003; Kurukulasuriya and Rosenthal, 2003). If agriculture becomes affected, then food security also becomes uncertain.

Food security occurs when individuals have continuous physical or economic access to adequate, harmless, and nourishing food to meet their dietary needs and food preferences for an active and healthy life (FAO and W.F.P., 2012). But the problem is that food security in the face of global climate change has become highly threatened since over one billion people around the world are underfed because they lack easy and constant access to affordable food (Cordell *et al*., 2009). It must also be noted, that the quantity produced (availability) of a particular crop which is also a function of food security is dependent on other factors such as land area, soil fertility and agronomic practices other than climatic factors of rainfall and temperature. It therefore becomes imperative for this study to take into account (besides rainfall and temperature) the impact of the size of the land area used for cultivation (which data was readily available at the time of this study unlike soil fertility and agronomic practices) since food security is being studied. As noted by Smith (2013), that food production can increase by expanding agricultural area. In other words, to be able to satisfy future food demand, then per-area productivity must increase. In support, Edgerton (2009) stressed that to satisfy the growing, worldwide demand for grain (maize), the area under production can be increased and or improved to boost productivity on the existing farmland.

The rapid pace at which climate change is happening, together with the increase in global population and slow income growth, threatens food security globally (Manyeruke *et al*, 2013). Agriculture has proven to be extremely susceptible to climate change as seen by the severe decline in food production over the past two decades, and that the high temperatures that are being experienced in most parts of the globe will eventually reduce yields of desirable crops while encouraging weed and pest proliferation (Manyeruke *et al*, 2013). The changes in precipitation patterns will significantly increase the likelihood of crop failures and production declines (Nelson *et al*, 2009, cited in Manyeruke *et al*, 2013).

All the four dimensions of food security are affected in one way or the other by climate change: that is food availability, food accessibility, food utilization and food systems stability (FAO and W.F.P., 2012). However the observed impacts indicates high effects on production aspects of food security rather than access or other components of food security (IPCC, 2014). For the purpose of this study, food security focused mainly on production (availability) component. Since agriculture (crop production) relates directly to or depends largely on climatic proxies of rainfall and temperature, changes (variations) in the pattern of these climatic proxies‟ impacts crop production hence to food security.

In Africa, low levels of food security and economic development conspire with high levels of climate risk (FAO and W.F.P., 2012). This is because agriculture systems in most countries in sub-Sahara Africa such as Ghana, Uganda, Cote d‟lvoire and Nigeria depend solely on rainfall. Therefore a slight delay in rainfall or unusual changes in rainfall pattern affect productivity levels greatly hence food security (IPCC, 2014). This has resulted in conscious effort on the part of farmers in these countries to adapt to such changes in rainfall pattern and temperature extremes through diversity of means ranging from irrigation to undertaking non-farm activities.

1.2. PROBLEM STATEMENT

A report by The High Level Panel of Experts on Food Security and Nutrition [HLPE (2012)] states that the adverse effects of climate change are already apparent in some regions and the eventual effect in all regions is likely to be very negative. Various reports by the Intergovernmental Panel on Climate Change (IPCC; 2001, 2014) have also indicated that Africa is one of the most exposed continents to the devastating effects of climate change and climate variability, because it often lacks adaptive capacity. Now the threat of climate change to national development in Ghana is officially acknowledged so commitments and efforts are being put in place to address the climate change concerns by agriculturalists and Ghana Trade Unions (Otoo and Asafu-Adjaye, 2014).

Agriculture in Ghana is a predominant economic activity which determines not only the livelihoods of the farmers but also an indicator of national growth and development since it contributes to employment creation and a source of revenue to the government as well as national food security (MoFA, 2010). A report by Ministry of Food and Agriculture [MoFA, (2013)] says the crop production sector of agriculture contributes about 66.2% to Ghana‟s Gross Domestic product (GDP). Ghana‟s economy is noted as primary resource-based, dominated by food crop cultivation therefore, extreme weather conditions and other environmental effects associated with climate change portend real danger to agricultural livelihoods and socioeconomic development of the country (Otoo and Asafu-Adjaye, 2014). Also the study area, Bibiani-Ahwiaso Bekwai (BAB) District is importantly noted for the production of food crops such as plantain, maize, cassava and vegetables as well as cash crops like cocoa and oil palm and is basically rain fed (MoFA, 2013; GSS, 2014) Since agricultural (food crop production) activities in the area depends largely on rainfall, food security at the district level becomes threatened if the district is adversely affected by uncertainties in rainfall patterns and other extreme weather events like floods, droughts and windstorms.

Matters concerning climate change and agriculture have attracted the attention of a number of researchers and research institutions globally (IPCC 2014; and Manyeruke *et al.*, 2013). This therefore affirms the existence of CC as a serious problem of concern for developing countries like Ghana since agricultural activities are dependent largely on climatic variables like rainfall and temperature, hence more research work must be conducted. However, literature on climate change has largely focused on the broad impact of climate change on livelihoods, adaption and mitigation strategies. For instance studies by Fosu-Mensah *et al.*, (2012); Nhamo *et al.*, (2014); Okonya *et al.*, (2013); and Apata, (2011) have all given attention to the broad effects of climate change on agriculture as a whole as well as various adaptation measures employed by farmers to cope. Also a study by Manyeruke *et al.*, (2013) considered climate change and its effects on agriculture as a whole (which includes growing of crops and raising of animals). Moreover the literature have focused on either using qualitative method alone or purely quantitative method to look at climate change and crop production. For instance studies by Smith and Malik, (2012) and Satishkumar *et al.*, (2013), adopted a purely qualitative approaches to examine various types of adaptations used by local farmers against climate change in low-income countries as well as the various constraints to adaptation. Uddin *et al.*, (2014) for instance also adopted the logistic regression (purely quantitative) to look at climate change impacts and adaptation measures used by farmers.

The above notwithstanding, the literature on climate change (CC) impacts on agriculture (Fosu-Mensah *et al.*, 2012; Nhamo *et al.*, 2014; Okonya *et al.*, 2013; and Apata, 2011) is silent on the actual impacts of climate change on individual crops as well as the stage or point in the production process where these impacts are greatly felt. The impacts of land area on quantity produced of a particular crop in the face of CC and the use of mixed method to study climate change impacts on crop production are also illexplored. These therefore leaves a lacuna in the area of investigating the impact of climate change on various crops individually hence this study.

This research therefore sought to fill this gap by focusing on the use of the mixed research method with both quantitative and qualitative procedures to look at the impact of some climatic proxies like rainfall and temperature among others on output of specific staple crops like cassava, maize and plantain in the Bibiani-Ahwiaso-Bekwai district from 1984 to 2014. Furthermore, the study also examined farmers‟ perceptions on farming practices that contribute to CC, perceived impacts, adaptation strategies they adopt and the determinants of such adaptation measures.

1.3 RESEARCH QUESTIONS

The research sought to answer the following question so as to achieve the objectives.

1. What has been the trend of rainfall and temperature patterns from 1984 to 2014?
2. What impact has changes in temperature and rainfall patterns as well as land area had on output levels of maize, cassava and plantain?
3. What are the perceptions of farmers on local indicators of climate change and the point/stage in the production process at which CC affects crops?

4. What are the contributions of farming practices to climate change in the study area?
5. How are farmers adapting to CC and how effective are the adaptation strategies?
6. What are the strengths and weaknesses of institutional mitigation strategies?

1.4. OBJECTIVES

The general objective is to examine the impact of climate change on food security but more specifically to:

1. Determine the nature and magnitude of trend in rainfall and temperature patterns in the study area from 1984 to 2014.
2. Examine the impact of CC (temperature and rainfall) and land area on yields of selected staple food crops (maize, cassava and plantain) from 1984 to 2014.
3. Assess farmers" perception on local indicators of climate change and the point/stage it affects crops in the production process in the study area.
4. Analyse the contributions of farming practices to climate change in the BAB district.
5. Analyse the determinants of adaptation to climate change by farmers in the area.
6. Assess the effectiveness of adaptation strategies to climate change in the area.
7. Assess strengths and weaknesses of institutional mitigation strategies

1.5. HYPOTHESES

H_0: There is no statistically significant trend in the rainfall pattern for the study area from 1984 to 2014.

H_1: There is statistically significant trend in the rainfall pattern for the study area from 1984 to 2014

H_0: There is no statistically significant trend in the temperature pattern for the study area from 1984 to 2014.

H_1: The trend in the temperature pattern for the study area from 1984 to 2014 is statistically significant

H_0: There is no statistically significant impact of changes in rainfall pattern on food crop (maize, cassava and plantain) yield.

H_1: There is statistically significant impact of changes in rainfall pattern on food crop (maize, cassava and plantain) yield.

H_0: There is no statistically significant impact of changes in temperature pattern on food crop (maize, cassava and plantain) yield.

H_1: The impact of changes in temperature pattern on food crop (maize, cassava and plantain) yield is statistically significant.

H_0: There is no statistically significant impact of land area/size on food crop (maize, cassava and plantain) yield.

H_1: There is statistically significant impact of land area/size on food crop (maize, cassava and plantain) yield.

H_0: There is no statistically significant relationship between perceptions of farmers on CC and the specific point in the production process that CC impacts crops.

H_1: There is statistically significant relationship between perceptions of farmers on CC and the specific point in the production process that CC impacts crops.

H_0: There is no statistically significant relationship between perceptions of farmers on CC and farming practices that contribute to CC

H_1: There is statistically significant relationship between perceptions of farmers on CC and farming practices that contribute to CC

1.6. PROPOSITIONS

1. Perceptions of farmers on climate change positively influence adaptation measures.
2. Effectiveness of adaptation measures is positively influenced by institutional mitigation strategies.

1.7. CONTRIBUTIONS OF THE STUDY

Methodologically, the study has helped to diversify the predominantly qualitative way of studying climate change impacts on crop production. The adoption of mixed method and the inclusion of the Ordinary Least Squares (OLS) model in assessing the impacts of rainfall and temperature as well as land area on output of selected staple crops (maize, cassava and plantain) has brought dynamism in inquiry methods to the discourse. An idea of how individual crops respond to changes in climatic variables is also achieved since the study tried to examine the impacts of changes in rainfall and temperature on output of selected staple crops.

Empirically, the analysis of the primary data adds up to the findings obtained from the secondary data therefore conclusions are made more factual and reliable. It has also confirmed findings of other empirical works in the literature such as studies by Onoh *et al*, (2014), Obayelu *et al*, (2014) and Uddin *et al*, (2014) which focused on various adaptation measures farmers adopt to cope with climate change. This is because the study used both primary and secondary data where the primary data elicited information from the field through administration of questionnaires and focus group discussions.

The OLS model and the Neo-Malthusian theory which anchors the tenets of the DPSIR model that drives this study of climate change impacts on crop output has helped provided a more reliable theoretical basis to the work and other literature in the field. Theories and models are considered the pivot in scientific research so once a study adopts same, the more reliable and valid the findings are likely to be. The credibility and acceptability of a study into scientific literature is thus dependent on how grounded and firm the study is in relation to theories.

In addition, the study also serves as a guide that gives policy makers more reliable information and recommendations based on which better decisions can be taken. Decisions on institutional mitigation strategies to climate change, a better way of educating farmers on climate change causes and impacts can easily be achieved. As highlighted earlier in the problem statement that once the cause of a problem is identified and its actual impacts can also be quantified, a more and better way of addressing the problem is achieved rather than basing on mere assumptions.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

This chapter reviews literature relevant to the theme of this study. In the first place, key definitions commonly used in the study have been provided and global evidence of climate change is reviewed. Again, influence of climatic change on food crop production has also been looked at. Also, influences of factors (such as land area) other than climate change on food crop production have thoroughly been reviewed. Finally food security, coping and adaptation to climate change by local farmers have all been looked at.

2.2. DEFINITION OF KEY TERMS

2.2.1. Climate, Climate Change (CC) and Climatic Variability

Agbola and Ojeleye (2007) defined climate as the mean state of the atmosphere of a location or an area over a defined period of 30 years. CC represents a significant difference between two mean climatic states or climatic normal with significant impact on the ecosystem (Agbola and Ojeleye, 2007). Climate change, according to Dadson (2008) refers to changes in the climatic variables or elements and more specifically, changes in temperature over time. He further opined that the term climate change is usually taken to mean changes in temperature though there are several climatic variables such as rainfall, clouds, humidity and winds etc. Saina *et al.* (2013) opined that many people consider CC as alteration of the world"s climate as induced by human activities through fossil fuel burning, deforestation and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. In line with this definition is the official definition by the United Nations Framework Convention on Climate
Change that states that CC is the change that can be attributed "directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The
Intergovernmental Panel on Climate Change (IPCC, 2001) defines "climate change" as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.
It is noteworthy from the definition by the UNFCCC (2007) above that a distinction is made between climate change attributable to human activities altering the atmospheric composition, and climate change attributable to natural causes.

Climate variability according to Bizikova *et al.* (2009) refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

For purposes of this study, climate change can be defined as observable statistical change in the major elements of climate including average temperature, wind and rainfall patterns caused by either natural means or anthropogenic factors over a considerable longer period of time. Climate variability on the other hand is the short term deviations of climatic proxies from the mean.

2.2.2. Mitigation

Mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system. That is it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (Saina *et al.*, 2013 and IPCC, 2014). According to Ifeanyi-obi and Nnadi, (2014), mitigation refers to measures that may either reduce the increase in greenhouse emissions or increase terrestrial storage of carbon (sequestration). From the above (UNFCCC, 2007; IPCC, 2014 and Pachauri *et al*, 2014), since human activities have been emphasized as contributing much to greenhouse gas concentration in the atmosphere which causes CC. Mitigation per this study implies all measures and strategies put in place by man that aim at stopping or preventing greenhouse gas emission into the atmosphere.

2.2.3. Adaptation

Adaptation is “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” (Saina *et al.*, 2013). The Intergovernmental Panel on Climate Change (IPCC, 2014) defines adaptation as a process of adjustment to actual or expected climate change and its effects. Ifeanyi-obi and Nnadi, (2014) also opined that adaptation refers to all the responses to climate change that may be used to reduce vulnerability. For the purpose of this study, adaptation simply involves taking pragmatic steps to cope with the changed climatic conditions over time.

2.2.4. Vulnerability

It implies the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. According to Bizikova *et al.* (2009), vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2014). Vulnerability is a function of the character of the system, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. In this study, vulnerability is taken to mean a disposition of how helpless crop producers are in the face of the devastating impacts of climate change. Helpless in terms of obtaining available and accessible resources to embark on adaptation strategies to enable them cope with climate change impacts.

2.2.5. Impacts

The term impacts is used primarily to refer to the effects of extreme weather and climate events and of climate change on natural systems and humans. Impacts generally refer to effects on lives, livelihoods, health, and ecosystems due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system (IPCC, 2014). Impacts are also referred to as consequences and outcomes. By extension to this study, impact refers to a decrease or increase in output of crops as a result of climate change.

2.2.6. Food security

Food security is a situation when at all times people have physical or economic access to sufficient safe and nutritious food to meet their dietary needs (Cordell *et al*, 2009). Global food security refers to the situation where each person, member of any household has physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO and W.F.P., 2012).

Climate change adds a new dimension of this challenge as it is one of the key drivers of change affecting the food system and contributing to rising food prices. It leads to changes in growing seasons and rainfall patterns and the increased frequency of extreme events such as droughts and floods. It has been estimated by the United Nations Environment Programme (UNEP, 2007) that up to 25 per cent of world food production could be lost by 2050 as a result of climate change, water scarcity and land degradation. Devereux and Maxwell (2001) observed that food and nutrition insecurity goes beyond inability of agriculture to produce adequate food at the national level, it also considered as inability of livelihoods to guarantee access to sufficient food at the household level. So to them, accessibility to sufficient food which is also a component of food security was highlighted in addition to food availability. For the purpose of this study, food security connotes a situation where producers have adequate produce available from their farms to supply to all people at all times.

2.3. CLIMATE CHANGE AND FOOD CROP PRODUCTION

Using the projected climate scenarios yields of cassava is expected to reduce with the rate of reduction increasing with time or rise in temperature. Cassava productivity or yields are expected to reduce by 3%, 13.5% and 53% in 2020, 2050 and 2080 respectively in Ghana (Sagoe, 2006). Further results also show that under climate change, crop yield changes are in the range of minus 17% to plus 6% at the national level. The implication is that climate change has empirically proven to have a non-linear relationship with output produced of food crop even though the negative effects outweighs the positive effects. In addition, Birthal *et al*. (2014) discovered in a study conducted in India that temperature has a non-linear effect on crop yields. This implies that whereas some crops would be significantly affected by changes in temperature, others would not.

Climate change is considered the greatest contemporary threat to food crop production especially in a developing country like Ghana. It is considered as one of the greatest environmental, social and economic threats the world has ever faced (IPCC, 2001; UNEP, 2007). It is real and happening faster than we previously thought with serious devastating impacts in developing countries, particularly on the Africa continent (IPCC, 2001). The poor countries in particular are the most vulnerable because of their high dependence on natural resources and their limited capacity to adapt to a changing climate (Desanker, 2002; FAO, 2012; IPCC, 2001). These impacts are expected to deepen poverty, food insecurity, poor livelihoods, dysfunction of infrastructural facilities, environmental resources and unsustainable development (FAO, 2012; IPCC, 2001).

Pimentel (1993) observed that changes in the world's climate will bring major shifts in food production. In some places, temperatures will rise and rainfall will increase; in others, rainfall will decrease. Such change, which affects soil temperature and moisture levels, also determines the vitality of both beneficial organisms and pests. Global warming is likely to alter the production of rice, wheat, corn, soybeans, and potatoes which serve as staples for billions of people and major food crops in both North America and Africa (Pimentel, 1993).

While climate change will have global impacts on agriculture, regional variations will be significant. Africa and North America exemplify the regional variations that may occur. These differences underscore the difficulty in proposing general strategies for adapting new agricultural technologies to deal with the climate change. By 2030, according to one scenario, atmospheric carbon dioxide concentrations will be doubled in concentrations and other greenhouse gases will increase substantially, and temperatures in North America and Africa will rise by approximately 2℃ (Pimentel, 1993). So if these changes occur, projected average rainfall in central North America will be 10 percent lower than now; in eastern and northern Africa, it may be 10 percent higher. While more rain holds the promise of increasing African agricultural productivity, higher temperatures may offset this advantage by decreasing soil moisture. As a result, dry agricultural regions may continue to suffer the effects of inadequate water supplies, even if levels of rainfall increase.

Agricultural production will be affected by the severity-and pace-of climate change. If change is gradual, there will be time for political and social institutions to adjust. Slow change also may enable natural biota to adapt (Pimentel, 1993). However, even a minor change (for example, one-tenth of a degree per decade) could spark significant changes in the frequency of climate extremes, including heat waves, floods, and droughts (Pimentel, 1993). Rapid climate change could jeopardize agriculture, forestry, and biodiversity worldwide (Pimentel, 1993). Compounding this problem is the fact that some African societies lack the capacity to adapt to these changes on their own (Pimentel, 1993). Moreover, because of climate change from global warming, the world may experience a dramatic change in food production regions: whereas some prime agricultural areas, such as the lower Midwest of North America, may suffer because of increased dryness, other areas, namely the Russian steppes, may actually become better suited for agriculture (Pimentel, 1993). Although it is too early to tell when these changes may occur, there is little question these climate changes will have a dramatic effect on human settlement and world food supplies (Pimentel, 1993).

2.4. LOCAL AND MACRO-SCALE IMPLICATIONS OF CLIMATE CHANGE FOR AGRICULTURE AND FOOD SECURITY

Newton *et al,* (2011) opined that climate change has already affected crop production and predictions are of accelerated effects. Agricultural systems worldwide over the last 40-50 years have responded to the effects of the interacting driving forces of population increase, income growth, urbanization and globalization on food production, markets and consumption (Von Braun, 2007). To these forces can be added the twin elements of climate variability and climate change which have direct effects on both food production and food security (Parry *et al*., 2004). Although climate change may benefit crop production in northern latitudes above 55^0, where warmer temperatures may extend the growing season, in the developing world (especially sub-Saharan Africa) the projected changes are likely to have negative impact and will further complicate the achievement of food security. This is due to the observed and predicted harmful impacts of climate change on agriculture, in particular in tropical and sub-tropical countries (Newton *et al*. 2011; Parry *et al*. 2004).

Newton *et al*. (2011) modelled the spatial variation in effects of climate change anticipated in 2050 on potential yields of rain-fed cereal crops worldwide and demonstrated that cereal producing regions of Canada, and northern Europe and Russia might be expected to increase production, while many other parts of the world would suffer losses, including the western edge of the USA prairies, eastern Brazil, Western Australia and many, though not all, parts of Africa.

The Third Assessment Report of the IPCC, (2001) projects that, areas that are currently dry are likely to experience an average increased dryness with global warming. Although the issue of food security is directly linked to climate change (Reilly, 1995), it must be noted that climate is not the single determinant of yields, nor is the physical environment the only decisive factor in shaping food security (Parry *et al*., 2004).

Impact of climate change on crop production and food availability should be a priority area for governments around the world if food self-sufficiency and security are to be achieved (Smith and Malik, 2012). This is because climate change directly affects agricultural production and food availability. This is primarily due to the fact that agriculture is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impacts of global climate change (Parry *et al.*, 2004).

Agricultural production, taken to mean food availability per this study which is also a function of food security in many African countries and regions is likely to be severely compromised by climate change (IPCC, 2001). According to the Cordell *et al*., (2009), most African countries are net food importers, with between 25 percent and 50 percent of food consumed in sub-Saharan Africa being imported. Africa"s cereal import bill, for example, was estimated at about US$22 billion in 2008 and about US$10 billion in Sub-Saharan Africa in 2008, representing a 30 percent and 35 percent increase over the 2007 levels respectively.

The consensus of scientific opinion is that countries in the temperate, high-, and mid-latitude regions are generally likely to enjoy increased agricultural production, whereas countries in tropical and subtropical regions are likely to suffer agricultural losses as a result of climate change which will most likely impact negatively on food availability in coming decades (Arnell *et al.,* 2002; Devereux and Maxwell, 2001). It should be noted that the favourable assessment for temperate and high latitude regions is based primarily on analyses of changes in mean temperature and rainfall, with relatively little analysis done to take account of changes in variability and extremes (Arnell *et al.*, 2002).

In many developing countries, food accessibility is negatively influenced by inefficient and ineffective transport systems which retard the delivery of food items from producers to consumers. This in most cases creates artificial food shortages thereby pushing prices of food items up and making food inaccessible to the poor and vulnerable.

This is consistent with the findings of Mamudu *et al*, (2012) that increased heat stress as a result of climate change may reduce the life span of roads. They further observed that climate change may increase the frequency and severity of windstorms which impact negatively on transit at air and sea port terminals as well as damaging infrastructure which may create delays in food transports thereby creating food accessibility problems. Another concern is the fact that people move to marginal lands to produce during harsh climatic conditions such as droughts. Unfortunately, most marginal lands do not have access roads and transport systems which make transportation of food items produced in such marginal areas to consumption centres a huge challenge with serious consequences on food accessibility (Mamudu *et al.*, 2012).

From the foregoing, climate change ultimately influences household food security. It affects food availability, accessibility, utilisation and stability in general. Low household income as a consequence of climate change impact on output translates into the inability of households to diversify their diets, generating situations of chronic malnutrition and poor livelihoods. It also leads to deterioration in food quality due to increased temperatures and lack of refrigeration equipment and water scarcity generating health hazards and poor living conditions especially among poor and vulnerable households who depend on agriculture for their survival (Mamudu *et al.,* 2012).

2.5. OTHER FACTORS INFLUENCING FOOD CROP PRODUCTION APART FROM CLIMATE CHANGE

2.5.1. Pest and disease attack

If climate change raises the temperature to $2^{o}C$ in the United States and slightly less in Africa, insects will multiply and prosper (Pimentel, 1993). During a growing season, some insects produce 500 offsprings per female every two weeks. Rising temperatures will lengthen the breeding season and increase the reproductive rate. That, in turn, will raise the total number of insects attacking a crop and subsequently increase crop losses. In addition, some insects, such as the South-western corn borer, will be able to extend their range northward as a result of the warming trend (Pimentel, 1993). Pests and diseases have great influence and adverse effects on crop production. Under the projected warming trend in the United States, farmers can expect a 25- to 100-percent increase in losses due to insects, depending on the crop. Because crop losses to insects in Africa are already high, the projected impact on different crops ranges from minus 30 percent for soybeans to plus 7 percent for rice. West Africa's warm, moist conditions are ideal for insects and crop diseases (Pimentel, 1993).

2.5.2. Land Area and Tenure system and crop production

Total land area used for cultivation is a key determinant to the overall quantity of yield farmers anticipate. In line with this, Smith (2013) observed that food production increases by expanding agricultural area or increasing per area production. It is therefore very important to consider or take into account the area cropped when considering crop production since climate change alone does not determine quantity of crop yield. The land tenure system in production is about the ownership of the land being used for cultivation of crops. If a piece of land is legally owned by an individual, he or she can make more gainful usage of it and give a better account on total output from it than those who rent the land or work for percentage (share) of the produce. Waiganjo and Ngugi, (2001) recalled that until recently the debate on the interface between land tenure and land use was restricted to enhance agricultural production. However land tenure, since it determines access to land is a critical variable in the management of natural and environmental resources, soil conservation, and water resources as well as wildlife management.

Land tenure provides the legal and normative framework within which all agricultural as well as other economic activities are conducted. Tenure insecurity whether customary or statutory, tenure regimes undermine the effectiveness of these activities. When tenure rights are certain, they provide incentives to use land in a sustainable manner or invest in resource conservation whether for the individual or group of individuals (Ogolla and Mugabe, 1996 cited in Waiganjo and Ngugi, 2001).

2.5.3. Transportation and crop production

There is substantial evidence that investments in roads and road connectivity positively affect agricultural productivity and output. Such evidence includes econometric analysis of sub national data about the effects of public spending (roads, agricultural research, education, and so on) on agricultural output, incomes, and poverty in the People"s Republic of China and India, which brought to light a positive

relationship between investment in road infrastructure and agricultural productivity (Fan and Hazell, 2001). Stifel and Minten, (2008) suggest that remoteness negatively affects agricultural productivity and incomes at the household level. This is relevant because, it is only the proportion of output that is accessible to the farmer can be accounted for and not the entire output from the farm which may not be accessible due to lack of better transport facilities. Moreover one"s ability to get access to one"s farm regularly due to better transport system would determine whether or not one can give proper attention to the farm for improved productivity.

The impacts of road infrastructure on agricultural output and productivity are particularly important in Sub-Saharan Africa for three reasons. First, the agricultural sector accounts for a large share of gross domestic product (GDP) in most Sub-Saharan countries. Second, poverty is concentrated in rural areas. Finally, the relatively low levels of road infrastructure and long average travel times result in high transaction costs for sales of agricultural inputs and outputs, and this limits agricultural productivity and growth. Thus, investments in road infrastructure can have a significant impact on rural and national incomes through their effects on agriculture (Stifel and Minten, 2008).

2.5.4. Soil fertility and crop production

The quantity produced of a particular crop is a function of soil fertility all things being equal. Soil productivity is the ability of a soil to support crop production determined by the entire spectrum of its physical, chemical and biological attributes (Schoenholtz *et al*., 2000). For the farmer, the decisive property of soils is their chemical fertility and physical condition, which determines their potential to produce crops. Good natural or improved soil fertility is essential for successful cropping. Crop production is based largely on soils. For large-scale and low-cost crop production, there is no substitute for natural soils as a substrate for crops in the foreseeable future (Schoenholtz *et al*., 2000).

2.6 THEORETICAL FRAMEWORK

The choice of the DPSIR model to drive the tenets of the study was informed by the Neo-Malthusians theory which came to add more meaning to Robert Thomas Malthus

Theory concerning population growth which represents the drivers in the DPSIR model and its consequences which also represent the impact component in the model.

Neo-Malthusians are a group of people who criticized some aspects of Malthus‟s ideology for instance "his insistence on the value of moral restraint as a way of reducing population growth and its consequences" while at the same time accepting many of his other conclusions (Weeks, 1999). Amongst them include Garret Hardin, Karl Marx, Friedrich Engels and Paul Ehrlich. Ehrlich (1968, cited in Weeks 1999) was arguably the most famous of all the neo-Malthusians.

Paul Ehrlich simplified the theory so preached by the neo-Malthusian in his book titled "Population Bomb" Ehrlich (1971; 2nd edition: cited in Weeks 1999). He phrased the situation in three parts "*too many people*", "*too little food*" and added a wrinkle not foreseen directly by Malthus, "*environmental degradation*". Ehrlich thus called the earth a "dying planet". The level of concern about the destruction of the environment as a result of rapid population growth has grown tremendously since 1968 (Ehrlich 1990; cited in Weeks 1999).

Like Hardin, Ehrlich feels that population growth is outstripping resources and ruining the environment. Ehrlich rightly questioned why in the face of the serious environmental degradation that has concerned him for so long, people have regularly failed to grasp its primary cause as being rapid population growth. He stressed that arresting population growth should be second in importance only to avoiding nuclear war on humanity‟s agenda. He concluded that overpopulation and rapid population growth are intimately connected with most aspects of the current human predicament, including rapid depletion of non-renewable resources, deterioration of the environment including climate change (Ehrlich and Ehrlich 1990:18; cited in Weeks 1999: pg. 86, 87).

The DPSIR framework adopted to study climate change and its impacts on food security is well place in the Neo-Malthusian theory of rapid population growth leading to environmental degradation. The rapid population growth by Ehrlich represents the driving-forces in the model which compel people to engage in one kind of activity or the other, example agriculture and or bush burning. In an attempt to provide adequate food to feed the growing population through agriculture, Pressure is exerted on the environment to change its state – in this case from virgin forest to bare land or desert environment. To them as highlighted earlier by Malthus, the place of technology in productivity may be paramount but may also lead to pollution of all kinds which results in the phenomenon of "*positive checks by nature*". Positive checks here implies the consequences such as famine or starvation, and its attendants ailments that nature has put in place to check overpopulation through mortality. Climate change is another evidence of a change in the state of the environment largely induced by anthropogenic factors such as deforestation for agricultural purposes.

When the state of the environment is altered – as in the case of climate change, it impacts agricultural activities negatively leading to food insecurity which is described earlier as famine and starvation by Malthus. Situations of such magnitude call for global concern that require response in order to cope with the impacts thereof either collectively as nations or individually

2.7. CONCEPTUAL FRAMEWORK

The conceptual framework intended to provide a foundation to this research is the **Driving forces-Pressure-State-Impact- Response (DPSIR) Framework**. The DPSIR framework is an extension of the Pressure-State-Response (PSR) model, developed by Anthony Friend in the 1970s, and subsequently adopted by the Organization for Economic Cooperation and Development's (OECD) State of the Environment group. The DPSIR framework is a supportive framework assuming a chain of causal links between driving forces and the resulting environmental pressures, on the state of the environment, the impacts resulting from changes in environmental quality and the eventual societal responses to these changes in the environment (OECD, 1993). In short the DPSIR framework focuses on what has gone wrong with the environment and how to fix it.

It is based on the fact that certain underlying factors force a variety of variables to be of necessity to humans. Human activities thus exert pressure on the natural environment and lead to changes in its state. These changes in state (and sometimes the environmental flows themselves) have impacts on human society. People then decide and act - often collectively or via governments and policy - to respond and address the pressures and impacts either by reducing the effects after they happen or by changing the driving forces or sources and preventing or minimising the environmental flows causing harm. The conceptual framework underpinning the relevance of the model is illustrated in Figures, 2 .1, 2.2 and 2.3.

Driving forces are underlying factors influencing a variety of relevant variables. Examples: the total amount of food available per inhabitant; total crop production; GDP. They are the determinants of livelihood activities that leads to the tilling of the land for crop production. The driving forces such as increase in family size, poverty and poor living standards compel people to exploit the environment indiscriminately giving least consideration to possible consequences of their actions. In an attempt to respond to such driving forces, man exert pressure on the environment (OECD, 1993).

The pressures are defined here as the stresses that human activities exert on the environment. They are often classified into underlying factors such as population growth, consumption or poverty. If as a results of poverty or high population growth, humans are compelled to cut wood to burn charcoal, clear the land to grow crops and excavate the soil for minerals then the pressures puts on the environment would ultimately result to a change in its state (OECD, 1993).

The state component refers to the condition of the environment resulting from the pressures; for example, the level of air pollution, land degradation or deforestation. The state of the environment in turn affects human health and well-being as well as the socioeconomic fabric of society. For example, increased land degradation leads to one or a combination of the following: decreased food production, increased food imports, increased fertilizer use and malnutrition.

The impacts component refers to the long term negative effects and manifestations arising from the change in state of the environment due to pressure. Absence of vegetation cover due to deforestation can change rainfall pattern and increase atmospheric temperature – a phenomena called climate change. The erratic rainfall pattern results in reduction in output of crops which would in turn lead to food insecurity. Knowing both the state of the environment and its indirect effects is critical for decision-makers and the public (OECD, 1993).

The response component of the model corresponds to societal action taken collectively or individually to ease or prevent negative environmental impacts, correct environmental damage, or conserve natural resources. Responses may include regulatory action, environmental or research expenditures, public opinion, consumer preferences, changes in management strategies, providing environmental information, and other coping strategies (OECD, 1993). These responses are normally measures that need to be taken to address the impacts. These responses need to be crafted to minimize the impact of the drivers and pressures on ecosystems and maximize the welfare of human beings (OECD, 1993). It is important to distinguish between coping and adaptation strategies. While, coping strategies undermine capacities of the people to respond to future threats, adaptation actions aim to create proactive responses that help build future capacities (Bizikova *et al.*, 2009).

2.7.1 Summary of the DPSIR framework, benefits and application areas

Driving forces are the social, demographic and economic developments in a city. They also include livelihood options, changes in lifestyles, poverty levels and consumption as well as production patterns. These driving forces exert pressure on the environment. For example, the excessive use of natural resources such as forests for firewood or land for urban agriculture. Over-utilization of forests for firewood may lead to deforestation and land degradation, and urban agriculture may contribute to soil erosion and siltation of rivers, depending on how the land is managed. These pressures change the state of the environment and such changes may have environmental, social and economic impacts. These may eventually affect human health as well as economic and social welfare of a society. Society is then forced to intervene to limit the damage or restore degraded areas. This may be in the form of by-laws, as well as budget allocations for monitoring and law enforcement.

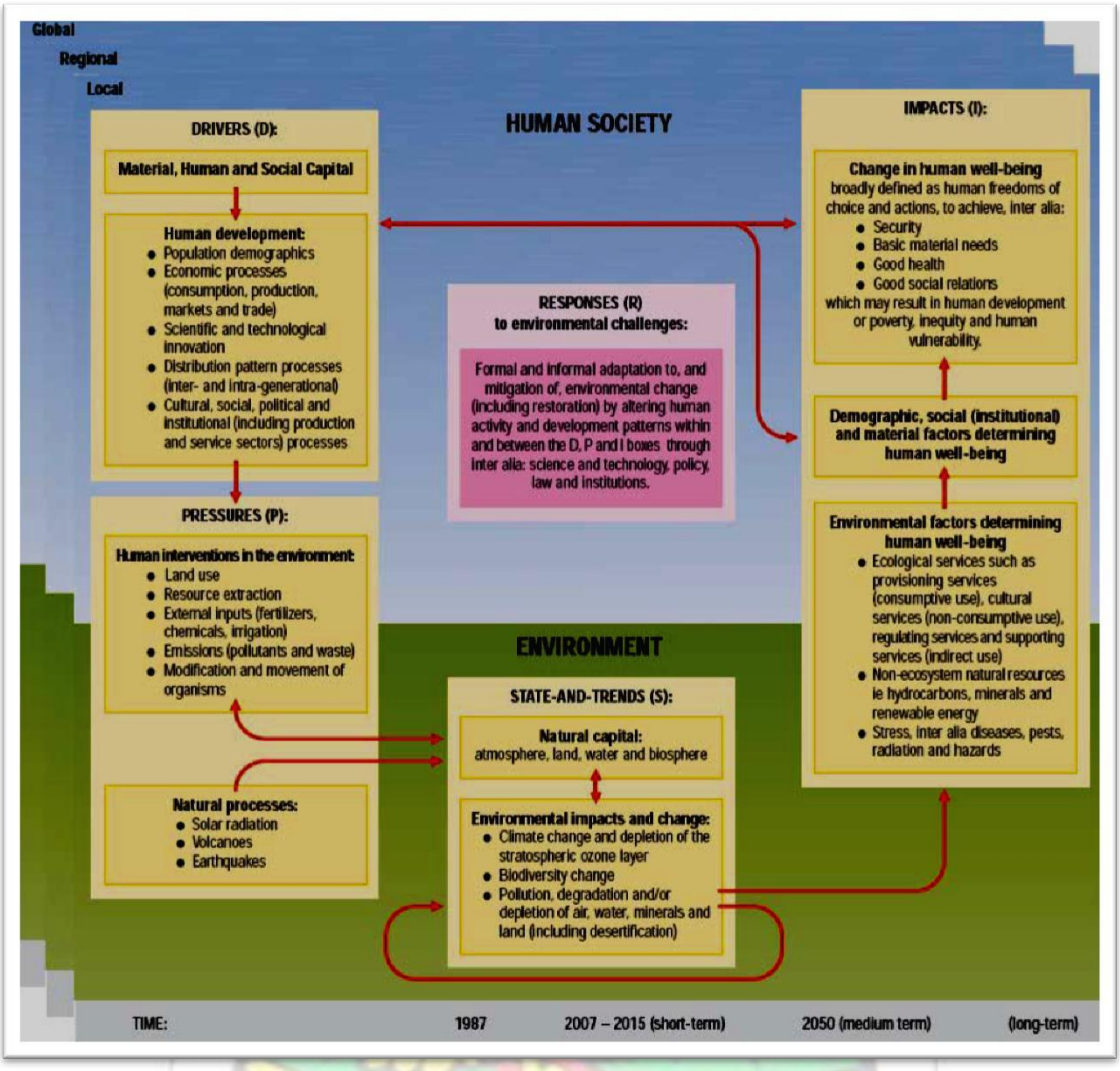
The framework helps to design environmental impact assessments, to identify indicators and to communicate results. It can also be used to integrate socio-economic and ecological processes to understand the forces that drive patterns of ecosystem changes, both in scientific studies, and as in policy processes.

The DPSIR framework can be used at any spatial level to address the need for reliable environmental data and information for effecting policy responses for better environmental management. It is also used as a tool by governmental organisations, marine construction companies, scientists, consultants and NGO‟s to get grip on various aspects of the effects of human activities on the environment. Again, it is possible to use the DPSIR framework within all phases of a project from the initiation phase through planning and design phase, construction phase, operation and maintenance phase and to decommissioning phase.

The model is very popular in terms of acceptance and its application globally. It has been applied in several instances most especially before the commencement and execution of development projects where Environmental Impact Assessment (EIA) is required in the process. For instance it has widely been adopted and used in many Integrated Environmental Assessment (IEA) processes for environmental assessment and reporting in Africa (OECD, 1993).

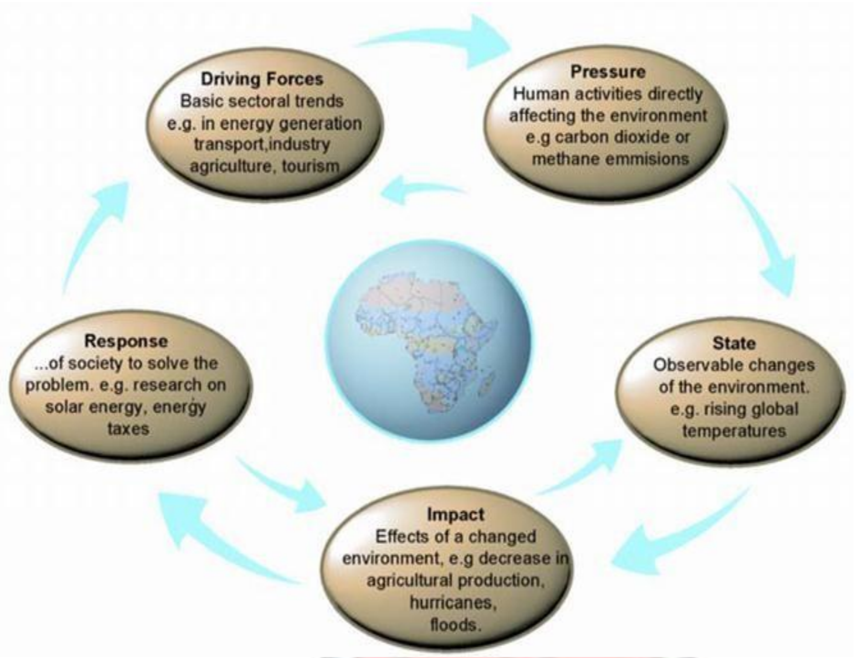
The tool was applied in the Singapore case of the Building with Nature (BwN) programme to structure information on environmental risks and impacts ensuing from various activities in the coastal zone (other than dredging). Here the focus was on water quality aspects, with the emphasis on pressures, state and impacts (OECD, 1993).

Figure 2.1 The Driver-Pressure-State-Impact-Response Framework based on UNEP's Human - Environment interaction analytical approach.



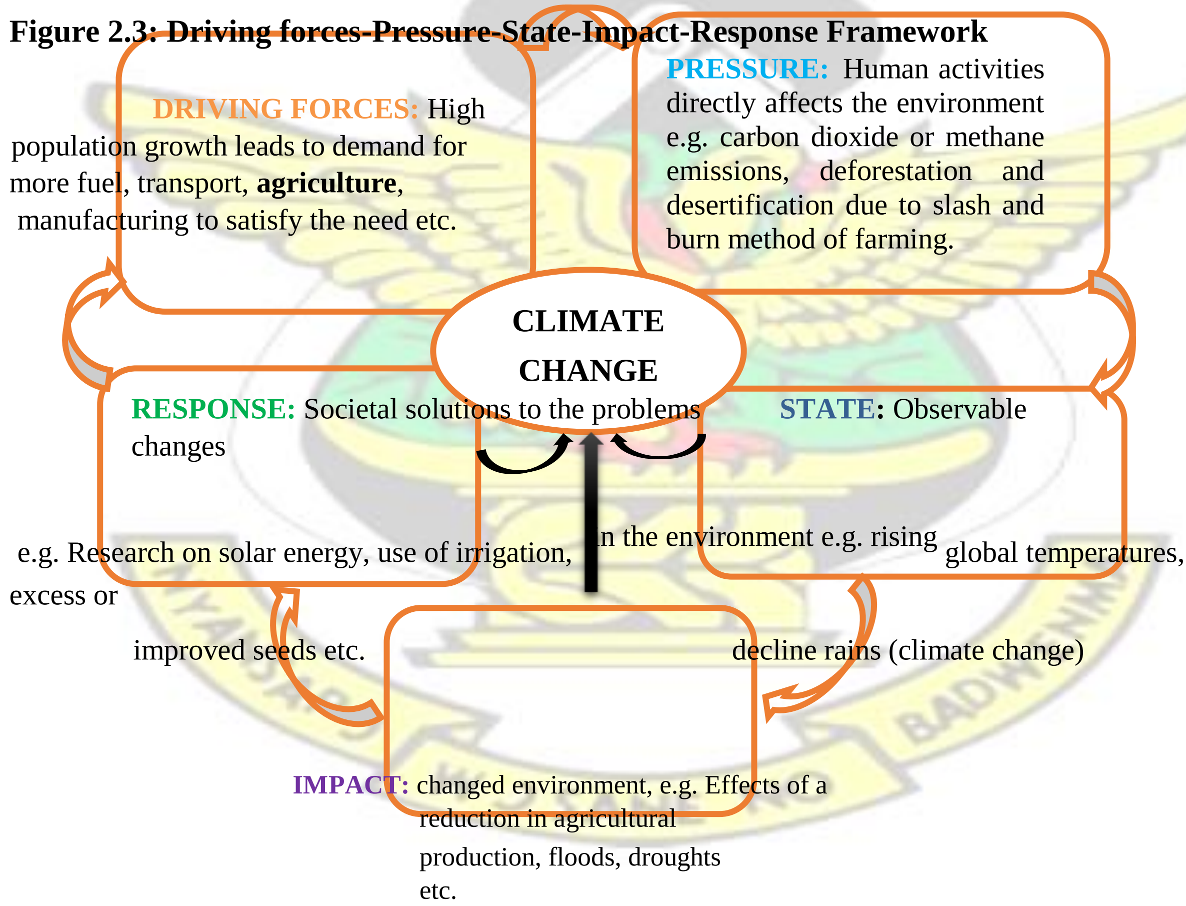
Source: OECD (1993)

Figure 2.2 DPSIR Model Simplified



Source: OECD (1993)

Figure 2.3: Driving forces-Pressure-State-Impact-Response Framework



(Source: Adapted from OECD, 1993)

CHAPTER THREE

PROFILE OF BIBIANI-AHWIASO-BEKWAI DISTRICT AND RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter looks at the biophysical and socio-demographic features of the Bibiani-Ahwiaso-Bekwai District (BAB). Specific features that the study focused on include: location and size, topography and drainage, population and occupation, soil, vegetation and climate. The chapter also considers the methodology adopted in conducting the research. The research design and approach, types and sources of data, unit of analysis or population, sample size and sampling techniques, instruments for data collection as well as techniques for data analysis have all been discussed in this chapter.

It is necessary to have an insight into the biophysical characteristics of the study district. This is because the study concerns climate change and food crop security (production / availability), which implies that the characteristics of the soil and vegetation types in the area give a clue to the type of crops that are likely to do well or thrive within such vegetation zones. That also goes to support the choice of crops suitable for investigation since certain kinds of crops such as shea-tree and millet are not typical of moist semi-deciduous forests vegetation as in the case of BAB district. Also, whether or not it is possible to practice irrigation as an adaptation measure against climate change depends on the availability of water sources within the frontiers of the study area. This therefore makes the description of drainage characteristics of the area very important. Insight into the historical climatic characteristics of the area is also import because vegetation as well as soil and for that matter crops of a particular area are functions of the micro climatic conditions of that particular area.

3.2. PROFILE OF STUDY AREA

The study area is the Bibiani-Ahwiaso-Bekwai district in the Western Region of Ghana. The district was particularly chosen for this study because of its prime place in the production of food crops in the country.

3.2.1. Location and size

In absolute terms, the Bibiani-Ahwiaso-Bekwai District is located between latitudes $6^{\circ}\ 3^{1}$ N and longitudes $2^{\circ}\ 3^{1}$ W (source: www.ghanadistrict.com). In relative terms, the district is located at the north-eastern part of the Western region of Ghana. It is bounded on the north by the Atwima Mponua district in the Ashanti region, south by the Wassa-Amenfi district in the Western region, west by the Sefwi Wiawso district in the Western region and east by the Denkyira North district and Amansie East district in the Central region and Ashanti region respectively. Bibiani, the district capital is 88km from Kumasi in the Ashanti Region and 356km from the regional capital, Sekondi-Takoradi. The district covers an area of 873 square kilometers representing 8.6% of the total land area of Western region. Figure 3.1 shows the outlined map of Bibiani-Ahwiaso-Bekwai District with specific study locations highlighted in rectangles.

Figure 3.1: Bibiani – Ahwiaso – Bekwai District Map Showing the Study Area

3.2.2. Topography and Drainage

The area falls within the forest dissected plateau of Ghana and is underlain by Precambrian rocks of the Birimian and Tarkwaian formation. The district"s terrain averages 350 metres above sea level with isolated peaks reaching 567 metres. The highest point in the district and for that matter, the entire Western Region is about 660 metres at Atanyamekrom, near Awaso (source: www.ghanadistrict.com).

Rivers in the district are in the closed forest. The major one is River Ankobra, which source is in the district. The other rivers forming the tributaries of the Ankobra include, Awa, Krodua, Atronsu, Subriso, Krosieni, Akaasu and Amponsah. They all join the main river at an acute angle like a tree and its branches to give it a perfect dendretic pattern. Some parts of the district are well drained especially where the place is noted for well-developed sandy soils that support the cultivation of groundnut whereas other parts are poorly drained due to the fact that the bedrock is an impermeable one and clayey soils (source: www.ghanadistrict.com).

3.2.3. Climate, Vegetation and Soils

The district is located in the wet semi-equatorial climate with an annual rainfall average of between 1200mm and 1500mm.The pattern is bimodal, falling between March – August and September- October. The dry season is noticeable between November-January and the peak rainy periods are June and October. The average temperature throughout the year is about 26°C. Temperatures are uniformly high throughout the district and rainfall is heavy. The combination of the two, translates into high relative humidity. There is a high relative humidity averaging between 75% in the afternoon and 95% in the night and early morning. The implication here is that the climate of the area is suitable and can facilitate the growing of most traditional and non- traditional crops for exports. Some of the traditional crops are cassava, yam and plantain.

The non-traditional crops also include pineapple and cashew (www.ghanadistricts.com).

The vegetation is moist semi-deciduous forest. In this area the tree species, examples Odum, Mahogany and Sapele form the basis of the flourishing Ghana‟s timber industry. Hence, the district is a suitable location for the establishment of timber firms.

The district is endowed with rich forest ochrosols conducive for the cultivation of both industrial and food crops. Forest oxysols are found around Sefwi Bekwai-Awaso area. These are rich in bauxite deposits extensively mined in the district (source: www.ghanadistricts.com).

3.2.4. Population and occupation

Total population is about 123,272 with 47.5% male and 52.5% female (GSS, 2014 cited at www.ghanadistrict.com). The agricultural sector is the most important sector employing more than half of the district‟s labour force. Specifically, the sector alone employs about 76 % of the labour force. Although the district has both rural and urban settlements, the rural settlements account for 63%. The implication here is that the district is basically rural; therefore agriculture can be used as a development focus in order to reduce poverty in the district. The district has three urban centers; Bibiani, Sefwi Bekwai and Awaso. These towns account for 37% of the total population, with the district capital (Bibiani) alone constituting 22.1% of the total population in the district (source: www.ghanadistrict.com).

From the foregoing it can be said that the dominant economic activity of the people in the district is purely primary. It includes agriculture, mining and lumbering. Agriculture being the leading economic activity comprises both cash and food crops. Common cash crops include cocoa, oil palm and coffee whereas maize, plantain, cassava, cocoyam, yam, tomatoes, pepper, okro, garden eggs, beans, cabbage and groundnut constitute the major food crops. Metallic minerals such as gold (mined at Bibiani and Chirano) and bauxite (mined at Awaso-Kainayirebo Mountain). Lumbering and charcoal burning tend to be other dominant activities in the area that seem to degenerate the rich forest into grassland. Most of these activities tend to pose a threat to the climate of the area (source: www.ghanadistrict.com).

3.2.5 Profile of Study communities

Six communities were selected for the study (as shown in figure 3.1; page 32) based on the intensity of their agricultural activities. They include Hwenampori, Wenchi, Tanoso, Awaso-Asempanaye, Kunkumso and Sefwi Bekwai. The number of households in each community from which respondents (being heads of households) were sampled is shown in Table 3.1 on page 40. Households and for that matter respondents in all the communities were primarily into food crop farming.

However, at Sefwi Bekwai, most respondents in addition to farming, were engaged in one kind of occupation or the other which is principally trading. This is because, Sefwi Bekwai aside being the largest among the study communities in terms of population and size or area, is also a commercial town with periodic market activities. In like manner, some residents of Awaso-Asempanaye were also engaged in bauxite mining as secondary occupation aside food crop farming as primary occupation. Similarly, Hwenampori is also very close to Bibiani the district capital and that gives the residents another opportunity of engaging in trading and some other commercial activities as secondary job besides their primary occupation being food crop farming. The story is quite different at Wenchi, Tanoso and Kunkumso where residents were predominantly into food crop farming. In any case an insignificant proportion of residents in these communities were engaged in other types of farming which were basically animal rearing namely piggery and poultry farming.

Farmers in this area practised mixed cropping. That is growing of two or more crops on the same piece of land at the same time. The predominant food crops produced in these communities include cassava, plantain, maize, yam and vegetables such as garden eggs, tomatoes, okro and pepper. Some of these farmers are subsistent farmers whereas others are commercial (www.ghanadistricts.com).

3.3. RESEARCH DESIGN

The study adopted the mixed research method to obtain and analyse the data. The mixed methods research design involves using both qualitative and quantitative methods of data collection and analysis in a single study (Creswell *et al*., 2003). In other words, a mixed methods study involves the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, given a priority, and involve the integration of the data at one or more stages in the process of research (Creswell *et al.*, 2003). This helps to provide a better understanding of the problem through the collection of a wide range of data that have both quantitative and qualitative basis. The method also helps to assess the actual impacts of climatic changes on food availability being a vital component of food
security.

3.4. DATA TYPES AND SOURCES

3.4.1 Secondary Data

The secondary data is made up of 31 years" (1984 to 2014) time series data points. It constitutes mainly the mean annual rainfall and the mean annual temperature for the period 1984 to 2014. It also includes the total annual output of maize, cassava and plantain in metric tonnes as well as the land area cultivated from 1984 to 2014. The reason for selecting 31years is due to insufficient data and the fact that 31 years duration is ideal for climate study. Climate according to Bizikova *et al,* (2009) is usually defined as ―average weather, described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the typical period is 30 years). Stated differently, the limitations to crop-yield data availability and accessibility influenced the selection of the period for the climatic data for the study. Also the reason for selecting these crops (maize, cassava and plantain) is that they are the predominant food crops cultivated by majority of households in the area (GSS, 2014 cited at www.ghanadistrict.com). Apart from the time series data, other secondary data include the total household data for the study areas.

The crop yield data (for maize, cassava and plantain) against the land area cropped was obtained from the Ministry of Food and Agriculture (MoFA) department in the district. The climate data was also sourced from the Ghana Meteorological Agency (GMA), Accra. Other secondary data like the total household data was obtained from Ghana Statistical Service (GSS) published reports and articles.

3.4.2 Primary Data

The primary data consist of information on the perceptions of farmers on micro indicators or manifestations of climate change over time in the area and how these indicators affect their activities. Specific information include farmers perceptions on farming practices that contribute to climate change, how changes in rainfall and temperature patterns and other locally observed extreme climatic events (such as drought, floods and windstorm) affect the annual production of the major staple crops (specifically maize, cassava and plantain) in the area. Again, information on the specific stage or point in the production process which the perceived climatic changes affect their crops and how they adapt to these changes were also sought for. Information on the determinants of the various adaptation measures and whether or not they are effective were also obtained. Finally, information on the existence of institutional adaptation or mitigation strategies or otherwise in the area were also sought for.

The primary data was sourced mainly from household heads from the study communities who are into production of maize, cassava and plantain. Since the focus of the study was on these specific staple crops, farmers who produced such crops were considered ideal for information bearing in mind their experience in the production of such crops and their

continuous dependence on rainfall for production. Other stakeholders such as officials from the district MoFA directorate and the District‟s Chief
Farmer were also contacted for information.

3.5 INSTRUMENTS FOR DATA COLLECTION

A field survey in the communities within the District was conducted between March 2015 and April 2015. Four main techniques were used in conducting the field research. They include administration of questionnaires to farmers, organization of focus group discussions with key informants, the use of structured interview guides on MoFA directorates and direct observation of some farms.

Questionnaires were administered with the help of four field assistants who proved invaluable in view of cultural barriers which confronted the researcher. Three of the field assistants were natives of the area therefore language barrier was easily overcome. Again the field assistants were particularly helpful with procedures for obtaining permission from local authorities. The questionnaires were administered at the convenience of the farmer both with respect to time and place. Again, the questionnaires which consisted of both close and open ended questions designed to cater for the objectives of the research were administered to the respondents in a conversational manner. In this case questions were read out to respondents since most of the farmers never had formal education or ended their education at a lower level and so reading, understanding and writing was a problem. In all, a total of 156 farmers were successfully interviewed with questionnaires during the period of the survey which lasted for three weeks.

Apart from the questionnaires, information was also obtained using Focused Group Discussion (FGD). Twelve (12) different FGDs were organized within the six communities where the study was conducted – two (2) in each community. Each group consisted of six (6) members on the average. They included members with at least 30 to 35 years farming experience who were also considered elders in food crop farming within each farming community. The discussions followed a flexible approach since they were guided by structured questions which was carefully designed for the purpose. This flexible approach became necessary in order to extract much information from the farmers. By encouraging the farmers to talk at length, information emerged which was not readily remembered or deliberately omitted as a result of farmers‟ mistrust of the motives of the research. It was therefore necessary to stress regularly, the independence of the study from government or its agencies.

An interview guide was also used to solicit information from MoFA directorate and the district chief farmer. With this, questions were designed to suit the objectives of the work and were posed to the respondent in a form of interaction where relevant information were extracted. Also, personal observations were made and some firsthand and relevant information were obtained when the field team visited some maize and plantain farms in some of the communities. In addition, various photographs and videos of some farms that were of interest to the study were taken or snapped. The photographs aided in providing clear visual information to supplement the verbal information obtained.

3.6. POPULATION

The targeted population consisted of officials from MoFA, GMA and heads of households who are food crop farmers from the study area. Only community members who have farmed for more than thirty years were presented with questionnaire against the background that they have more experience on climate change and its impacts than younger people. Amongst them were mainly experienced local farmers and key informants who could attest to noticeable changes in rainfall and temperature patterns, and traditional leaders who are involved in community decision-making.

3.7 SAMPLE SIZE

The district has a total household of 27,961 with 74.9% (i.e. 20,938) engaged in agriculture (GSS 2014 cited at www.ghanadistrict.com). Out of the 20,938, who are into agriculture, 98.2% (being 20,552) are food crop farmers that formed the sampling frame from which a total sample size of 231 respondents were selected and contacted for information to aid the final work. In all, 156 respondents out of the total sample size (231) were presented with questionnaires for information to aid quantitative data analysis and 75 respondents were also engaged in Focus Group Discussion (FGD) and or interviewed for information also for qualitative data analysis. The 156 sample size was determined using the formula by Yamane, (1967:886) cited in Israel, (1992:4) as shown in the equation.

$\boldsymbol{n = \frac{N}{1+N(e)^2}}$ Where:

n is the desired sample size **N**

is the target population and **e**

is the margin of error.

With 92% confidence level, 8% (0.08) margin of error was used to determine the sample size. By using 8% margin of error, the 156 sample size derived was representative enough of the population to draw conclusions. Another reason for choosing 8% margin of error is that the obtained sample size of 156 was only meant for questionnaire administration for quantitative data analysis besides the 75 respondents meant to provide qualitative information through FGD and interviews for qualitative analysis. Again, by reducing the margin of error the sample size was too high for the researcher to get adequate resources to gather data considering the time frame. Table 3.1 gives a summary of the sample size from the various communities which was proportionately determined.

Table 3.1 Details of Sample size.

	Total No of Households		Sample Size			
	Communities	Household Heads	Questionnaires	FGD/Interview Males	Females	Total
Bib. TA	Hwenampori	824	19	7	5	31
	Wenchi	617	14	7	8	29
Ahw. TA	Tanoso	647	15	7	5	30
	Kunkumso	439	10	6	7	23
Bek. TA	Awaso-Asempanaye	1473	34	5	5	44
	Sefwi Bekwai	2759	64	6	5	72
	MoFA Direc.		0	2		02
Total		6723	156	75		231

Source: GSS, 2014

3.8 SAMPLING TECHNIQUE

A total sample size of 156 study respondents were selected and presented with questionnaires using the simple random sampling technique due to the homogenous nature of households in the various study communities in terms of their occupation.

In order to ensure that each household gets equal chance of being included in the survey, house numbers of each community were written on identical papers, folded and put in a box. I then picked one, after thoroughly shaking the box. The same process was followed until the required sample size for each community was obtained. According to Patton (1987), random sampling is an appropriate strategy when one wants to generalize from the sample studied to some large population. Through random sampling there is increased likelihood that the data collected are a representative of the whole population of interest. The random sampling technique was preferred over others to select the individual farmers because with this method the probability of selection becomes the same for every case in the population. Another reason random sampling was used is to avoid bias by giving all units in the target population equal chances of being selected. Finally, the 75 respondents who were also interviewed and or engaged in FGD in the various communities were reached through special announcements via the community information system. With this, all food crop farmers who have at least thirty five years of farming experience in either maize, cassava and or plantain cultivation were invited to gather at a particular location for discussion. A total of twelve (12) different FGDs with average membership of six (6) in each group were held in the six (6) communities - two FGDs in each community, comprising one group for males and another group for females. The detail of the composition of group members in terms of gender and number is summarised in Table 3.1. Each discussion lasted for about one and half hours so we could adequately exhaust all themes meant for the discussion. Participants were eager in contributing and never showed any sign of boredom since they found the whole exercise very interesting. Two officers from the MoFA directorate who were readily available at time of the data collection, were also interviewed for more information to aid the work.

3.9 ETHICAL CONSIDERATIONS

Each time we entered a community, appropriate permission was sought from the officials of that community which mostly included the Assembly member of that electoral area and or the Chief ("Odikro" as chiefs are called by the local people) of that community. Besides, earlier contacts were made with traditional rulers and assembly persons of the selected communities to inform them of the purpose of the study and to seek their consent during the reconnaissance visits to the communities. All participants gave their consent prior to being interviewed and or given a questionnaire to respond to and that participation was strictly voluntary. Wahyuni (2012) recommends that the researcher starts off the interview by briefly explaining the aim of the interview and emphasizing the confidentiality, anonymity and the voluntary nature of the study. With the participant"s permission, some activities were recorded and treated confidential. Again, it must be emphasized that photographs and videos used in this study were all taken with consent of the respondents.

3.10. DATA ANALYSIS

3.10.1 Primary Data

The primary data was analysed using Content Analysis (CA). Content analysis is a technique for systematically describing written, spoken or visual communication (Krippendorff, 2012). It provides a quantitative (numerical) description. It is also used to analyse new material recorded by researchers, and to classify open-ended responses to interview or survey questions (Krippendorff, 2012). By using CA, common themes were drawn from the responses and direct quotes from the Focus Group Discussions (FGD). Through the FGD, opinion of respondents on such indicators as farmer"s perception on climate change, perceived impacts on their activities, the specific stage or point in the production process where rainfall and or temperature variability mostly affect their corps and some adaptation strategies that help them remain in production were put into themes and various sub-headings for discussion. Wahyuni (2012) observed that a common approach to the interpretation of meanings from textual data is using CA. It concentrates on portraying reality by discovering meanings from the textual data.

In addition, statistical tools such as Pearson Chi-Square and Cross tabulation of the IBM SPSS Version 20 were also used in performing descriptive statistical analysis. The Chi-Square test was used to determine the level of significance between the perceptions of farmers on changes in rainfall and temperature patterns and their effects on the cultivation of their crops as well as the determinants of adaptation strategies. A significant Chi-Square test results ($P < 0.05$) implies that the proportion of respondents in favour of an observed situation is significantly different from the proportion of respondents for the alternative observation. However, if the Chi-Square test results is not significant statistically, it mean that the proportion of respondents in favour of an observed situation does not differ significantly from the proportion of respondents in against the alternative observation.

Finally descriptive statistical tools such as frequencies and bar graphs were also used to present the results. A clearer visual impression was achieved when the bar graphs were used to present information. Again, where appropriate, photographs were used to give a visual image of the issues being presented.

3.10.2 Secondary Data

The secondary data was analysed with the aid of Microsoft Excel and Eviews software. Trend analysis was performed for rainfall and temperature from 1984 to 2014 using the MANN-KENDALL trend test. The impact of changes in rainfall, temperature patterns and land area on output levels of maize, cassava and plantain were analysed using the Multiple Linear Regression Model / Ordinary Least Squares (OLS) model. The Ordinary Least Squares (OLS) approach to multiple linear regression was introduced by Gauss in 1794. The OLS model naturally shows the long run impact of the independent variables (explanatory variables) on the dependent variable (explained). In this instance the independent variables include rainfall, temperature and land size and the dependent variables are maize, cassava and plantain.

The model is premised on some assumptions including:

- The Cov (X_i U_j) = 0 (thus there shouldn‟t be any relationship between the independent variables and the error term). This means that rainfall, temperature, and land area data that enter the model must be collected with minimal error. Thus the independent variables must be free from significant error.

- The Cov (X_i X_j) = 0 (thus there shouldn‟t be any association between the independent variables). In other words, rainfall, temperature and land area data that enter the model must not have any connection or link. Any connection amongst them will make it extremely difficult to separate the impact of each independent variable on the dependent variable (multicollinearity).

- The variability in the error term must be constant. Thus Var (μ_t) = δ^2. This also implies that the probable errors associated with the independent variables must not significantly differ one from another.

Based on these assumptions, the general multiple regression model is mathematically specified as:

$$Y = \beta_0 + \beta_1 \times_1 + \beta_2 \times_2 + \beta_3 \times_3 \ldots\ldots. + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$. Where;

Y is the dependent variable or the regressand which is also referred to as the explained variable. It represents the quantity we wish to explain variation in, or the variable we are trying to explain.

$X_1 \ldots X_3$ are the independent variables or explanatory variable or regressors. It represents a quantity whose variation will be used to explain variation in the dependent variable.

β_0 is the Y -intercept which corresponds to the expected value of Y when X = 0 (may or may not be meaningful). Typically we are more interested in β_1 than β_0, but β_0 forms a vital part of any regression estimation.

$\beta_1 \ldots \beta_3$ are the coefficients of the independent variables and μ_i is the error term. The coefficients determine the magnitude of the impact or the contributions of the independent variables on the dependent variable. In other words the regression coefficient refers to the expected change in Y resulting from a one-unit change in X. For example, whether or not the impact of rainfall on maize output would be positive (which implies increase in output) or negative (which also imply decrease in output) would be shown by the regression coefficient.

μ_t is the error term or the stochastic disturber.

But to solve the problem of non-constant variance of the error term (heteroskedasticity), to ensure that the model is in a linear form even without a scatter diagram and to ensure that the large figures are reduced to lowest form for easy interpretation, the regression model is linearised with the aid of the natural logarithm (ln). The transformed model which also captures the variables of the study is therefore given as:

$$LnMZ_t = \beta_0 + \beta_1 lnT_t + \beta_2 lnR_t + \beta_3 lnLA_t + \mu_t \dots\dots\dots\dots\dots\dots.(2)$$ For maize

$$LnCA_t = \beta_0 + \beta_1 lnT_t + \beta_2 lnR_t + \beta_3 lnLA_t + \mu_t \dots\dots\dots\dots\dots\dots.(3)$$ For cassava

$$LnPL_t = \beta_0 + \beta_1 lnT_t + \beta_2 lnR_t + \beta_3 lnLA_t + \mu_t \dots\dots\dots\dots\dots\dots.(4)$$ For plantain

Where;

$LnMZ_t$, $LnCA_t$, and $LnPL_t$ = Outputs of maize (2), cassava (3) and plantain (4) respectively in metric tonnes.

lnT_t = Mean Annual Temperature (°C) lnR_t = Total Annual Rainfall (mm) $lnLA_t$ = Land Area (hectares) μ_t = error term β_1..........β_3 = Coefficients of the independent variables (rainfall, temperature and land area).

Since the model is linearised with the natural logarithm, they do not represent unit changes any longer. The coefficients are therefore expressed in percentages after computation because the coefficients represent elasticities. For instance instead of attributing changes in maize, cassava and plantain output to unit changes in rainfall and or temperature, it is expressed as percentage changes.

3.10.3 Expectations of the coefficients (βs)

Temperature: Empirical studies which were based on three modelling methods (Agronomic-economic model, Agro-Ecological Zone modelling and Cross-Sectional analysis) cited in Koffi-Tessio (2009), suggest that developing countries agricultural systems are vulnerable to climate change because they tend to be less capital and technology intensive and they tend to be in climate zones which already border on being too hot and will likely get hotter. The agronomy results also suggest that warming alone would reduce most crop yields in developing countries (Koffi-Tessio, 2009).

Temperature increase is therefore expected to negatively impact output of food crop produced at the study area. Hence $\beta i < 0$.

Rainfall: The coefficient of rainfall is expected to have a positive relationship with output of maize, cassava and plantain. That is as the amount of rainfall increases the quantity produced of the various crops also increases all things being equal.

Land Area/size: A prior expectation of the coefficient of land area is that all things being equal, land area is expected to have a significant positive relationship with output of crops (maize, cassava and plantain) (Smith, 2013). Conventional knowledge has it that as the land area cultivated expands, more crops are likely to be grown and output increases.

3.10.4 Diagnostic Tests

The robustness and the efficacy of the Ordinary Least Square (OLS) model is determined by performing the diagnostic tests. Normality test, auto correlation test and heteroskedasticity test are conducted to assess the model estimated. This means that the strength of the model is determined by performing the diagnosis test which confirms that all fundamental assumptions are met. It also implies that whether or not the model is fit for running the data and to perform the analysis in order to determine the impact of rainfall, temperature and land area on output of maize, cassava and plantain is established by the test. Finally the reliability and the validity of the regression results can only be established when the test declares the results as being free from the problem of auto correlation and heteroskedasticity and is also normally distributed. In this case, the hypothesis of the diagnostic test ensures that the model is homoscedastic and free from auto or serial correlation and is also normally distributed.

3.10.4.1. Autocorrelation Test

The model assumes that errors of different observations are independent of each other. This implies that the values of the stochastic disturber μ assumed at any given time period has no association with its past values. It therefore suggests that the covariance of the error terms vanishes, which is symbolically written as Cov $(\mu_i, \mu_j) = 0$ where $i \neq j$. The violation of this assumption gives rise to the problem of autocorrelation or serial correlation of the stochastic error term. Omission of important variables in the model specification, systematic error in the measurement, misspecification of functional form are possible factors that can give rise to this problem of serial correlation of the error term. When the stochastic error term are serially correlated, the estimated parameter will be statistically unbiased however it renders the estimated parameters inefficient since the variances of the error term becomes large. The estimated variance of the parameters may be seriously underestimated hence the standard error and the t– statistic will be inflated. This may show that a particular coefficient may be statistically significant but in reality might not be so. It can render the conventional R^2 an unreliable measure of coefficient of determination.

The null hypothesis of no serial correlation is tested against an alternative hypothesis of serial correlation in the model. If the result is not significant, we fail to reject the null hypothesis; the null hypothesis is rejected indicating the existence of autocorrelation if the result is significant.

3.10.4.2. Normality Test

The model again assumes that the stochastic error term follows a normal distribution which is symbolically written as $\mu \sim N(0, \delta^2_u)$. It means that the error term is normally distributed around a zero mean and a constant variance δ^2_u. It therefore suggests a greater tendency of observing a smaller values of the error term as against large values. If the assumption of normality is violated, the classical t-statistic and Fstatistic of the parameter cannot be reliable even though the estimated coefficients are still unbiased. It tests the null hypothesis that the error term is not normally distributed against an alternative hypothesis that the error term is normally distributed.

3.10.4.3. Heteroskedasticity Test

The model assumes that the variance of the residuals is constant. Symbolically Var $(\mu_t)=\delta^2$. It means that the variance of the error term across observation is equal. Meaning the error term is assumed to be homoscedastic. When the assumption of constant variance of the error term is violated, the problem of heteroskedasticity arises. It is caused by omission of an important variable from the model specification and when the data set has large range of observation. This is because when the data has large range of observations, there is a possibility of outliers or extreme values in the data set which has a progressive tendency of pulling the variance of the error term. When the error term is heteroskedastic, the estimators will not have minimum variance and due to that confidence interval and the hypothesis testing based on the t and F-distribution would no longer be reliable.

CHAPTER FOUR

IMPACT OF RAINFALL, TEMPERATURE AND LAND AREA ON OUTPUT OF MAIZE, CASSAVA AND PLANTAIN CROPS

4.1. INTRODUCTION

This chapter first and foremost considers whether or not there has been a trend among climatic proxies of rainfall and temperature with the aid of MAKESENS trend test and also to determine the significance or otherwise of the trend. Again the chapter looks at the regression analysis and discussion of the secondary data performed with the Eviews software. The selected crops (maize, cassava and plantain) were regressed against all the explanatory variables (rainfall, temperature and land area) to assess the actual impact of these variables on the output of the crops separately. In that regard temperature, rainfall and land area were all regressed against cassava output. The same variables were regressed on maize and plantain outputs. Possible reasons that have empirical and theoretical underpinnings have been used to justify findings and results.

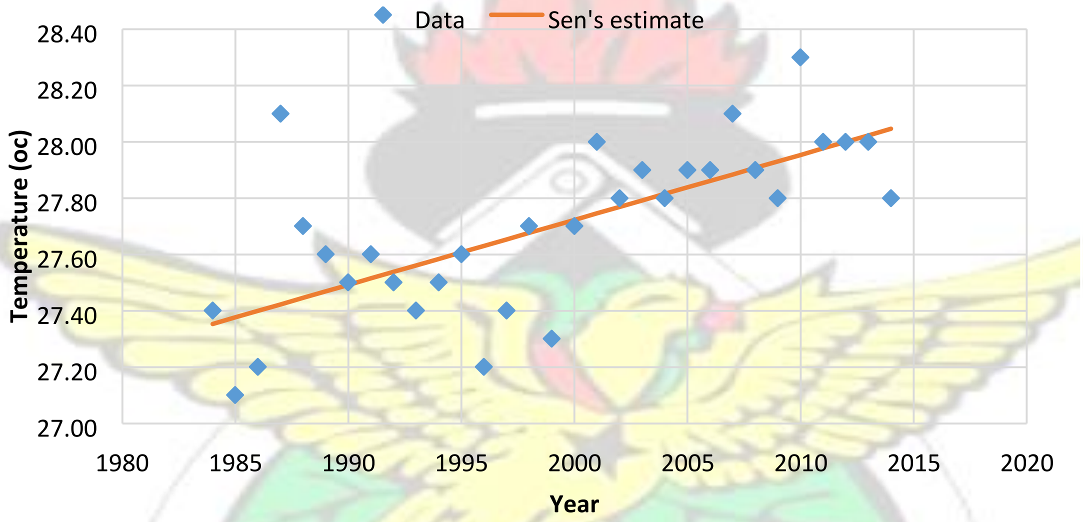
4.2 DETERMINATION OF TREND AMONG CLIMATIC PROXIES OF RAINFALL AND TEMPERATURE

In order to detect whether or not there is a trend and its level of significance in the rainfall and temperature variables over the period from 1984 to 2014, the Mann-Kendall trend test and the Sen‟s slope (MAKESENS) were used to run a simple test. The MAKESENS performs two types of statistical analyses. First, the presence of a monotonic increasing or decreasing trend is tested with the nonparametric Mann-Kendall test and secondly the slope of a linear trend is estimated with the nonparametric Sen‟s method (Gilbert, 1987). These methods are here used in their basic forms; the MannKendall test is suitable for cases where the trend may be assumed to be monotonic and thus no seasonal or other cycle is present in the data. The Sen‟s method uses a linear model to estimate the slope of the trend and the variance of the residuals to be constant in time (Gilbert, 1987).

These methods offer many advantages that have made them useful in analysing atmospheric chemistry data. For instance it provides a simple graphical interface that assists in the visual inspection of the time series and the statistical results. Missing values are allowed and the data need not conform to any particular distribution.

Besides, the Sen‟s method is not greatly affected by single data errors or outliers (Gilbert, 1987). Figures 4.1 and 4.2 show the trend of mean annual temperature and rainfall at the study district from 1984 to 2014.

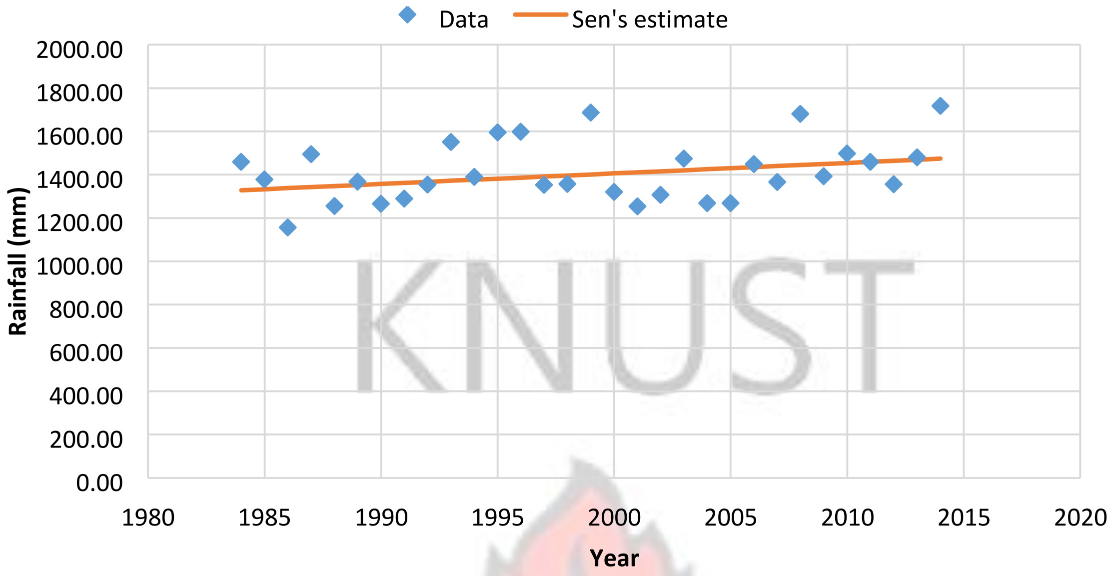
Figure 4.1 Trend of mean annual temperature (1984 – 2014) in the BibianiAhwiaso-Bekwai district.



Source: (Field data from GMA, 2015)

Temperature trend from 1984 to 2014 shows a positive slope which implies a monotonic increasing trend. The trend statistics also shows that the trend is highly significant (see Table 4.1 and Appendix (M)). By implication, the rate at which temperature is increasing over the years shows that it would continue to increase therefore crops that are less resistant to high temperatures will be significantly affected.

Figure 4.2 Trend of mean annual rainfall (1984 – 2014) in the Bibiani-AhwiasoBekwai district.



Source (Field data from GMA, 2015)

Figure 4.2 also shows a positive slope which implies that there is a monotonic increasing trend in the rainfall data set over the period. However, the trend statistics show that it is not significant (see Table 4.1 and Appendix (M)). This trend also has a negative implication on crops that require much water to ensure proper growth and development.

Table 4.1: Trend Statistics

BAB

				Mann-Kendall trend			Sen's slope estimate									
Time series	First year	Last Year	n	Test S	Test Z	Signific.	Q	Qmin99	Qmax99	Qmin95	Qmax95	B	Bmin99	Bmax99	Bmin95	Bmax95
OM	1984	2014	31		3.16	**	47.848	9.992	87.838	18.845	75.996	6372.41	6762.89	5694.59	6730.08	5990.04
LM	1984	2014	31		3.96	***	24.318	9.634	41.937	11.426	37.906	4722.05	4856.46	4477.76	4838.57	4529.75
Temp	1984	2014	31		3.97	***	0.023	0.012	0.033	0.015	0.031	27.35	27.53	27.17	27.49	27.21
Rain	1984	2014	31		1.63		4.856	-3.507	11.742	-0.872	10.626	1327.98	1446.85	1199.55	1386.27	1214.12
OC	1984	2014	31		0.32		22.700	-259.456	208.627	-161.377	159.019	74584.10	77644.46	70689.69	77546.38	71688.57
LC	1984	2014	31		-1.09		-6.522	-20.544	10.000	-16.261	4.059	7682.61	7932.52	7390.00	7845.13	7485.06
Op	1984	2014	31		0.88		176.923	-325.761	946.406	-210.430	707.956	96198.16	101206.80	84298.93	100540.72	87875.68
LP	1984	2014	31		0.53		2.778	-21.407	66.588	-12.642	52.248	9930.00	10121.61	9335.53	10030.78	9483.02
0	0	0	0													

***, ** and * represent significance at 1%, 5% and 10% levels respectively.

Source (Field data from GMA, 2015)

4.3. IMPACT OF RAINFALL, TEMPERATURE AND LAND AREA ON MAIZE OUTPUT IN THE STUDY AREA

The OLS model for maize is specified as:

$$LnMZ_t = \beta_0 + \beta_1 \, lnT_t + \beta_2 \, lnR_t + \beta_3 \, lnLA_t + \mu_t$$

4.3.1 Diagnostic Test Results for Maize

The results of the diagnostic tests conducted are presented, analysed and discussed here. Results of autocorrelation test of error terms, normality test and heteroskedasticity test are presented below.

The test results of autocorrelation is presented in appendix (C) with the aid of Breush-Godfrey Lagrange Multiplier (LM) test. Autocorrelation LM test reports the multivariate LM test statistics for residuals serial correlation. Since the null hypothesis is insignificant at all the output levels as shown in appendix (C), the null hypothesis of no autocorrelation cannot be rejected. Therefore the stochastic error terms are not associated or correlated hence the model is free from the problem of autocorrelation of the residuals.

The result of the normality test presented in appendix (B) reveals that the chisquared results of skewness and kurtosis are not statistically significant so is the result of the Jacque-Bera statistic. Therefore the null hypothesis of normality in the stochastic error term cannot be rejected. The model is thus normally distributed.

The chi-square test at both the joint and individual components levels are not significant as shown in appendix (D). Therefore the null hypothesis of no heteroskedasticity cannot be rejected.

Table 4.2. Ordinary Least Squares (OLS) Results for Maize

Regressors	Coefficient	Std. Error	t-Statistics	Prob.
LandArea/size Ha	1.970040	0.143479	13.73048	0.0000
Rainfall (mm)	-0.636676	0.382743	-1.663456	0.1074
Temperature (^{0}C)	-72.96117	30.24064	-2.412686	0.0226

R-Squared	0.880402
Adjusted R-Squared	0.871860

Source (GMA, 2015 and MoFA, 2015)

Land Area

The coefficient of Land Area (LA) measures the impact or the proportion of maize output that is attributed to land area cropped with maize. The regression results (Table 4.2), shows that a percentage increase in the size of the land area for cultivation of maize results in a 1.970040 percent increase in output of maize in metric tonnes holding rainfall and temperature constant. The coefficient of 1.970040 which is greater than 1% implies that maize output is more elastic (responsive) to increase in land area. This is consistent with a study by Tariq *et al* (2014) where regression results showed that an increase in land area is positively related with wheat production. This finding is also consistent with conventional agricultural and geographic knowledge on crop production. This is because as the land area expands it creates avenue for better cultural practices in agriculture such as thinning out and pruning for proper aeration. It also gives enough space for effective disease control and planning for appropriate drainage system. It also goes to support the fact that much more crops can be cultivated on a large land area compared to small land area and also in accordance with extension services standards.

In addition, the P value from (Table 4.2) is 0.0000 which also implies that the impact of land area/size on maize output is highly significant holding other variables constant. From the above findings it can be concluded that land size is a key determinant of the quantity produced of maize and other food crops in Ghana but it is least mentioned in most climate change and crop production studies. The size of the land area devoted to the cropping of a given food crop type and the fertility of the soil should all be looked at whenever climate change and food crop production studies are being carried out. This is because if the land area cropped with a particular food cropped is not factored in the studies, one may conclude by either underrating the potential of the size of the land in the quantity produced of a particular crop or attribute a particular observation in relation to quantity produced of a particular food crop to rainfall or temperature.

Rainfall

The coefficient of rainfall (mm) also measures the impact or the proportion of maize output that is attributed to rainfall. The result from Table 4.2 indicates that a one percent increase in the amount of rainfall leads to a 0.636676 percent decrease in output of maize holding other variables constant. Rainfall impact on maize is more elastic implying that proportionate increase in rainfall reduces maize productivity. A similar observation was made by the IPCC (2014) with medium confidence that climate change has negatively affected maize yields for many regions and in the global aggregate. It is therefore not surprising to unearth a decrease in output of maize as a result of climate change in the current study.

Even though changes in rainfall reduces maize output, the probability value (Pvalue) of 0.1074 reveals that it is not significant (Table 4.2). Therefore the null hypothesis of no statistically significant impact of changes in rainfall pattern on output of maize cannot be rejected. That is we fail to reject the H_0. It is important to note that, even though impact of rainfall on maize output is not statistically significant, it does not mean rainfall is less important in maize production. On the contrary, the non-significance is in relation to the drastic impact (decrease) of rainfall on maize output. This can partly be attributed to plant physiology that categorise maize as an example of C4 plant (Roberts, 1986). For C4 plants, they have inherent resilient mechanism to grow and produce, therefore they are able to fix more carbon dioxide (CO_2) into sugar. They thus have the ability to produce more even in the absence of optimum conditions as in the case of rainfall and temperature extremes

(Roberts, 1986). This phenomena therefore explains to some extent the reason why the reduction (negative impact) in maize output is not

statistically significant.

The impact of rainfall on maize output from (Table 4.2) can again be partly attributed to the very small variation in the rainfall data over the study period; thus the

Coefficient of Variation (CV) in rainfall is very insignificant [CV = $\frac{SD}{x}$]. The MAKESENS trend statistics also identified a non-significant trend in the rainfall data set over the 31 years period. This observation is consistent with a study by Birthal *et al.*, (2014) whose study on climate change and food security observed, that if changes in climate are not significant, damages to crops will be smaller and that in the short run too, climate change impacts will not be so severe.

Besides, maize is also a seasonal crop since it is cultivated only in the rainy season especially among farmers in developing countries whose farming activities are basically rain fed. Being a seasonal crop, climate change (manifested in either excessive or inadequate rainfall or even unreliable rainfall pattern) does not significantly affect the output of maize so much compared to other perennial crops. Exceptions are true during instances of extreme weather events like heavy windstorms that tend to pull down large expanse of maize farms where farmers‟ observations at such moments assume damages and loses to be more significant as shown in chapter five.

Temperature

The coefficient of temperature measures the impact or the proportion of maize output that is attributed to temperature. Again the results reveal that a percentage increase in temperature leads to 72.96117 percent fall in maize production holding other variables constant (Table 4.2). Temperature is more elastic to maize production implying that a proportionate increase in temperature drastically reduces maize productivity by more than just a proportionate.

The probability value of 0.0226 implies that temperature impacts on maize output is significant so the null hypothesis cannot be accepted. The alternative hypothesis which states that „there is statistically significant impact of changes in temperature on maize output" is accepted. Excessively high temperatures has high potentials of damaging crops especially during some critical stages in the production process (such as germination stage and or fruit development stage – (Detailed discussion in Chapter five). Roberts (1986) pointed out that high temperatures affect the rate of biological reaction in living systems thereby reducing productivity. This is because enzymes activities are inhibited in situations of increased temperatures (Roberts, 1986), and this explains why increase in temperature significantly impacted output of maize negatively (Table 4.2). Lobell and Field (2007) also discovered in a study (Global scale climate–crop yield relationships and the impacts of recent warming) that maize and other cereals have proven clearly to be negatively affected by increase in temperature.

The R-squared (coefficient of determination) shows the goodness of fit of the model and how proportionately the variations in the dependent variable is jointly explained by the independent variables. The R^2- squared value of 0.880402 (Table 4.2) means that approximately 88% of the total variability in maize output has been explained jointly by land area, rainfall and temperature. The 88% thus signifies that the model is good and robust, and that the results are highly reliable for predictions and decision making.

The overall significance and the performance of the regression model is given by the F-statistic. The F-statistic tests the joint significance of all the explanatory variables in the regression model. The F-statistic with k-1 and n-k degree of freedom permits us to test the hypothesis that none of the explanatory variables is capable of explaining the variations in the explained variable about its mean. Thus:

$H_0: \beta_1 = \beta_2 = \beta_3 = \ldots\ldots\ldots\ldots = \beta_i = 0$

H_1: At least $\beta_i \neq 0$

The F- statistic is calculated as:

$$F = \frac{R^2/(K-1)}{(1-R^2)/(n-K)} \sim F_{\alpha,k-1,n-k}$$

From the E-view results (Table 4.2), $R^2 = 0.880402$, the number of explanatory variables (k) = 3 and the sample size (n) = 31.

$\therefore F = [0.880402] \div 2 / [1-0.880402] \div 28 = 103.0588$

On that basis F-statistic =103.0588.

The F-critical $[F_{\alpha}$, k-1,n-k] from the statistical table, $F_{0.05}$, 2, 28 = 3.34

It also follows that if the F- statistic (F-calculated) exceeds the F-critical, we reject H_0 otherwise we fail to reject H_0. Since F-statistic [103.0588] is greater than F- critical [3.34], we reject H_0. Meaning that rainfall, temperature and land area combined, do significantly influence the output of maize in the study area. When quantity produced is negatively affected by the climate change, then food security is obviously at risk. The IPCC (2014) WGII AR5 summary for policymakers concluded that the observed impacts of climate change on food (which is generally negative globally in all regions) is related mainly to production aspects (availability) of food security rather than accessibility or other components of food security which are food utilization and food systems stability.

4.4 IMPACT OF RAINFALL, TEMPERATURE AND LAND AREA ON CASSAVA OUTPUT IN THE STUDY AREA

The OLS model for cassava is specified as:

$$LnCA_t = \beta_0 + \beta_1 lnT_t + \beta_2 lnR_t + \beta_3 lnLA_t + \mu_t$$

4.4.1 Results of the Diagnostic Test for Cassava Model

The results of the diagnostic tests conducted for cassava model are presented and analysed here. Test results of autocorrelation of error terms, normality and heteroskedasticity are presented below.

The test result of autocorrelation of the model specified for cassava is presented in appendix (G) with the aid of Breush-Godfrey Lagrange Multiplier (LM) test. Autocorrelation LM test reports the multivariate LM test statistics for residuals serial correlation. Since the null hypothesis is not significant at any of the output levels (see appendix G), the null hypothesis of no autocorrelation cannot be rejected. Therefore the stochastic error terms are not associated or correlated hence the model is free from the problem of autocorrelation of the residuals

The result of the normality test for cassava model presented in appendix (F) reveals that the chi-squared results of skewness and kurtosis are statistically insignificant so is the results of the Jacque-Bera statistic. Therefore the null hypothesis of normality in the stochastic error term cannot be rejected. The model is thus normally distributed.

The chi-square test in the appendix (H) at both the joint and individual components level are insignificant. Therefore the null hypothesis of no heteroskedasticity cannot be rejected.

Table 4.3. Ordinary Least Squares (OLS) Results for Cassava

Regressors	Coefficient	Std. Error	t-Statistics	Prob.
Land Area/Size(Ha)	11.14157	1.521180	7.324298	0.000
Rainfall (mm)	-6.547095	4.522217	-1.447762	0.1588
Temperature (^{0}C)	-8.494679	470.1725	-0.018067	0.9857

R-squared	0.657164
Adjusted R-squared	0,632676

Source (GMA 2015 and MoFA, 2015)

Land Area

The coefficient of Land Area (LA) measures the impact or the proportion of cassava output that is attributed to land area. From the regression results (Table 4.3), a percentage increase in the size of the land area for cultivation of cassava triggers an 11.14157 percent increase in output of cassava in metric tonnes holding rainfall and temperature constant. The coefficient of 11.14157 which is greater than 1% implies that cassava output is more elastic (responsive) to increase in land area. This finding is consistent with conventional agricultural and geographic knowledge on crop production. This is because as the land area expands it creates avenue for thinning out and pruning for proper aeration. It also gives enough space for effective disease control and planning for appropriate drainage system. It also goes to support the fact that much more crops can be cultivated on a large land area compared to small land area.

The P value from (Table 4.3) is 0.0000 and it implies that the impact of land area/size on cassava output is highly significant at 1% level of significance holding other variables constant. From the above findings it can be concluded that land size is a key determinant to quantity produced of cassava and other food crops in Ghana but it is least mentioned in most climate change and crop production studies.

Rainfall

The coefficient of rainfall measures the impact or the proportion of cassava output that is attributed to rainfall. The result from (Table 4.3) indicates that a one percent increase in the amount of rainfall leads to a 6.547095 percent decrease in output of cassava holding other variables constant. The impact of rainfall on cassava output is more elastic implying that a proportionate increase in rainfall drastically reduces cassava productivity. Some possible reasons based on plant physiology have it that cassava as a crop grows best in well drained soils requiring little rainfall to mature the tubers. Excess water therefore affects the starch content in the tuber causing them to rot in the presence of high temperatures. A minimal supply of water and warmth is therefore required to ensure that tubers mature well to increase output. Climate change (manifested in either excessive or inadequate rainfall or even unreliable rainfall pattern) has proven to affect output of cassava negatively.

Even though rainfall drastically reduces cassava productivity, the probability value (P-value) of 0.1588 reveals that it is not significant (Table 4.3). Therefore the null hypothesis of no statistically significant impact of changes in rainfall pattern on output of cassava cannot be rejected. That is we fail to reject the H_0.

It is important to note, that the fact that impact of rainfall on cassava productivity is not statistically significant does not mean rainfall is less important in cassava production. Contrary the non-significance is in relation to the drastic impact (decrease) of rainfall on cassava production. This to a large extent can be attributed to the very small variation in the rainfall data over the study period; thus the Coefficient of Variation (CV) in rainfall is not significant [CV $= \frac{SD}{X}$]. This observation is consistent with a study by Birthal *et al.*, (2014) whose study on climate change impact on food security discovered that if changes in climate are not significant, damages to crops will be smaller and that in the short run too, climate change impacts will not be so severe.

Temperature

The coefficient of temperature measures the impact or the proportion of cassava output that is attributed to temperature. Again the results reveal that a percentage increase in temperature leads to an 8.494679 percent fall in cassava output holding other variables constant (Table 4.3). Here temperature is more elastic to cassava production implying that a proportionate increase in temperature drastically reduces cassava production by more than one percent.

However, the probability value of 0.9857 implies that the temperature impact is not significant so the null hypothesis cannot be rejected. This can partly be explained by the very small variation in the temperature data over the study period; thus the Coefficient of Variation (CV) in temperature is very insignificant [CV $= \frac{SD}{\bar{x}}$]. An observation consistent with the finding of a study by Birthal *et al.*, (2014) on climate change impacts on food security, which observed that if changes in climate are not significant, damages to crops will be smaller and that in the short run too, climate change impacts will not be so severe.

The R-squared (coefficient of determination) indicates the goodness of fit of the model and how proportionate the variations in the dependent variable is jointly explained by the independent variables. From the (Table 4.3), the R-squared value of 0.657164 which is approximately 66% implies that the total variability in cassava output has been jointly explained by land area, rainfall and temperature. The 66% by approximation signifies that the model is good and robust.

The overall significance and the performance of the regression model for cassava is given by the F-statistic. The F-statistic tests the joint significance of all the explanatory variables in the regression model. The F-statistic with k-1 and n-k degree of freedom permits us to test the hypothesis that none of the explanatory variables is capable of explaining the variations in the explained variable about its mean. Thus:

$H_0: \beta_1 = \beta_2 = \beta_3 = \ldots\ldots\ldots\ldots = \beta_i = 0$

H_1: At least $\beta_i \neq 0$

The F- statistic is calculated as:

$$F = \frac{R^2 / (K-1)}{(1-R^2)/(n-K)} \sim F_{\alpha, k-1, n-k}$$

From the E-view results, $R^2 = 0.657164$, the number of explanatory variables (k) = 3 and the sample size (n) = 31 (Table 4.3).

$$\therefore F = [0.657164] \div 2 / [1-0.657164] \div 28 = 26.8359$$

On that basis F-statistic = 26. 8359

The F-critical $[F_{\alpha,}$ k-1,n-k] from the statistical table, $F_{0.05}$, 2, 28 = 3.34

It also follows that if the F- statistic (F-calculated) exceeds the F-critical, we reject H_0 otherwise we fail to reject H_0. Since F-statistic [26.8359] is greater than F- critical [3.34], we reject H_0. This means that rainfall, temperature and land area combined, do significantly influence the output of cassava in the study area.

4.5 IMPACT OF RAINFALL, TEMPERATURE AND LAND AREA ON OUTPUT OF PLANTAIN IN THE STUDY AREA

The OLS model for Plantain is specified as:

$$LnPL_t = \beta_0 + \beta_1 \ln T_t + \beta_2 \ln R_t + \beta_3 \ln LA_t + \mu_t$$

4.5.1 Results of the Diagnostic tests for Plantain Model

Results of the diagnostic tests conducted are presented and analysed here. Results of autocorrelation of error terms, normality and heteroskedasticity tests conducted on the regression model for plantain are presented below.

The result of the test conducted on the regression model for plantain output is presented in Appendix (K) with the aid of Breush-Godfrey Lagrange Multiplier (LM) test. Autocorrelation LM test reports the multivariate LM test statistics for residuals serial correlation. Since the null hypothesis is not significant at any of the output levels (see appendix K), the null hypothesis of no autocorrelation cannot be rejected. Therefore the stochastic error terms are not associated or correlated and that makes the model free from the problem of autocorrelation of the residuals.

The results of the normality test presented in Appendix (J) reveal that the chisquare results of skewness and kurtosis are not statistically significant and so is the result of the Jacque-Bera statistic. Therefore the null hypothesis of normality in the stochastic error term cannot be rejected.

The results of the chi-square test conducted on the regression model for plantain at both the joint and individual component levels are not significant (see appendix L). Therefore the null hypothesis of no heteroskedasticity cannot be rejected.

Table 4.4. Ordinary Least Squares (OLS) Results for Plantain

Regressors	Coefficient	Std. Error	t-Statistic	Prob.
Land Area	11.68982	1.405252	8.318666	0.0000
Rainfall	6.843917	8.353561	0.819281	0.4195
Temperature	-1005.846	677.0046	-1.485730	0.1485
R-Squared		0.721722		
Adjusted R-squared		0.701845		

Source (GMA 2015 and MoFA, 2015)

Land Area

The coefficient of Land Area (LA) in the OLS model for plantain measures the impact or the proportion of plantain output that is attributed to land area. From the regression results in Table 4.4, a percentage increase in the size of the land area for cultivation of plantain triggers an 11.68982 percent increase in output of plantain in metric tonnes holding rainfall and temperature constant. The coefficient of 11.68982 which is greater than 1% implies that plantain output is more elastic (responsive) to increase in land area. This finding is consistent with conventional agricultural and geographic knowledge on crop production, that as the land area expands it creates avenue for thinning out and pruning which ensure proper aeration. It also gives enough space for effective disease control and planning for appropriate drainage system. It also goes to support the fact that much more crops can be cultivated on a large land area compared to small land area and according to extension services standards.

In addition, the P value from Table 4.4 is 0.0000 which also implies that the impact of land area/size on plantain output is highly significant holding other variables constant.

From the above findings it can be concluded that land size is a key determinant to quantity produced of plantain and other food crops in Ghana but it is least mentioned in most climate change and crop production studies.

Rainfall

The coefficient of rainfall measures the impact or the proportion of plantain output that is attributed to rainfall. The OLS results of the impact of rainfall on plantain indicates that a one percent increase in the amount of rainfall leads to a 6.843917 percent increase in output of plantain holding other variables constant (Table 4.4). Rainfall impacts on plantain is more elastic implying that a proportionate increase in rainfall is translated to a proportionate increase in plantain productivity. Even though an increase in rainfall results in a rise in plantain productivity, the probability value (P-value) of 0.4195 (Table 4.4) reveals that it is not significant. Therefore the null hypothesis of no statistically significant impact of changes in rainfall amount on output of plantain cannot be rejected. That is we fail to reject the H_0.

It is important to note that, the impact of the rainfall on plantain output which is not significant does not mean rainfall is less important in plantain production. On the contrary, it is the drastic impact (increase in output of plantain) of rainfall on plantain production that is not significant. This can partly be attributed to the very small variation in the rainfall data over the study period; thus the Coefficient of Variation (CV) in rainfall is very insignificant [CV = $\frac{SD}{X}$]. This observation is consistent with the findings of a study by Birthal *et al* (2014) on climate change impacts on food security, which observed that if changes in climate are not significant, damages to crops will be smaller and that in the short run too, climate change impacts will not be so severe.

Temperature

The coefficient of temperature measures the impact or the proportion of plantain output that is attributed to temperature. Again the results reveal that a percentage increase in temperature leads to a 1005.846 percent fall in plantain output holding other variables constant (Table 4.4). Here temperature is more elastic to plantain production implying that a proportionate increase in temperature drastically reduces plantain output by more than one percent.

The probability value of 0.1485 (Table 4.4) however, implies that the impact of temperature is not significant so the null hypothesis cannot be rejected. This can partly be attributed to the very small variation in the temperature data over the study period; thus the Coefficient of Variation (CV) in temperature is very insignificant [CV = $\frac{SD}{X}$].
This observation is consistent with the findings of a study by Birthal *et al.*, (2014) on the impact of climate change on food security, which observed that if changes in climate are not significant, damages to crops will be smaller and that in the short run too, climate change impacts will not be so severe.

The R-square (coefficient of determination) shows the goodness of fit of the model and how proportionately the variations in the output of plantain is jointly explained by the changes in rainfall, temperature and land area. From Table 4.4, the Rsquared value of 0.721722 which is approximately 72% of the total variability in plantain output has been explained by land area, rainfall and temperature. The 72% signifies that the model is good and robust.

The overall significance and the performance of the regression model for plantain is given by the F-statistic. The F-statistic tests the joint significance of all the explanatory variables in the regression model. It will be useless when applied to a single regression model because, we can obtain the same information from the t-ratio of the individual parameters or coefficient. The F-statistic with k-1 and n-k degree of freedom permits us to test the hypothesis that none of the explanatory variables in the regression model for plantain is capable of explaining the variations in the explained variable about its mean. Thus:

H_0: $\beta_1 = \beta_2 = \beta_3 = \ldots\ldots\ldots\ldots = \beta_i = 0$

H_1: At least $\beta_i \neq 0$

The F- statistic is calculated as:

$$F = \frac{R^2 \div (K-1)}{(1-R^2) \div (n-K)} \sim F_{\alpha, k-1, n-k}$$

From the E-view results, $R^2 = 0.721722$, the number of explanatory variables (k) = 3 and the sample size (n) = 31 (Table 4.4).

$\therefore$ F = [0.721722 ÷ 2] / [(1-0.721722) ÷ 28] = 36.3094

On that basis F-statistic = 36.3094

The F-critical [F_{α}, k-1,n-k] from the statistical table, $F_{0.05}$, 2, 28 = 3.34

It then follows that if the F- statistic (F-calculated) exceeds the F-critical, we reject H_0 otherwise we fail to reject H_0. Since F-statistic [36.3094] is greater than F- critical [3.34], we reject H_0. This means that rainfall, temperature and land area combined, do significantly influence the output of plantain in the study area.

In sum, and as highlighted in the impact component of the DPSIR framework being the focus of this study, the chapter sought to look at the existence and magnitude of trend in rainfall and temperature variables in the study area as well as the impact of the changes in rainfall, temperature and land size (area) on output of maize, cassava and plantain by using the MAKESENS and OLS model respectively. It was observed that there was a significant increasing trend in the temperature pattern and a non-significant increasing trend in the rainfall pattern in the study area. Again, it was revealed that the size the land area cropped had a significant positive impact on output of all the crops (maize cassava, and plantain). Also, the results revealed that an increase in temperature results in a significant fall in output of maize whereas a decrease in output of cassava and plantain as a result of increase in temperature was not significant. Finally, an increase in rainfall was also observed to result in increased output of plantain and a decreased output of cassava and maize. It can therefore be concluded that climate change which is revealed by the trend test as significant increase in temperature and rainfall in the study area has a significant impact on output (availability) of staple crops such as maize, cassava and plantain in the study area. From the DPSIR framework, which drives the tenets of this study, it is observed that when there is a change in the state of the environment (such as climate change) as a result of pressure, it leads to significant impact on environmental constituents such as crops and other biodiversity.

Apart from the findings from the secondary data as shown by the regression results analysed above, empirical information on impacts of the variations of same climatic variables (rainfall and temperature) on the same crops (maize, plantain and cassava) from farmers perspective have also been considered in the next chapter.

CHAPTER FIVE

FARMERS PERCEPTION ON CLIMATE CHANGE IMPACT ON CROP OUTPUT AND ADAPTATION STRATEGIES

5.1. INTRODUCTION

The previous chapter focused on the regression analyses of the secondary data using the Ordinary Least Squares (OLS) model. This brought to light some significant impacts and relationships that exist among rainfall and temperature as main climatic proxies and output of maize, cassava and plantain. But in order to draw better conclusions, empirical information from farmers‟ experiences, observations and perceptions concerning climate change and food crop production have also been captured and analysed here. This chapter looked at the analyses and discussion of the primary data obtained from the field. Cross tabulation, and Pearson‟s chi-square were the main tools used to test the levels of significance in terms of association of farmers‟ responses concerning their perceptions on climate change (CC), farming practices that contribute to CC, aggregate impact on their activities, farmers‟ adaptive strategies, determinants of adaptation and effectiveness of institutional mitigation strategies.

The results obtained from the statistical analyses have been supported with findings and concerns through direct quotations and generalization of ideas from farmers during the focus group discussions. Appropriate literature that are consistent or otherwise with the results have also been used to support the findings obtained.

5.2. PERCEPTION OF FARMERS ON THE KIND OF OBSERVED CLIMATE CHANGE EVENT/ LOCAL INDICATORS OF CLIMATE CHANGE (CC).

Table 5.1 Cross tabulation of observed CC and the kind of climate event

			Kind of climate change			Total
			floods	Dry spells	Strong winds	
Observed CC	Yes	Count	30	57	55	142
		% of Total	19.5%	37.0%	35.7%	92.2%
	No	Count	3	3	6	12
		% of Total	1.9%	1.9%	3.9%	7.8%
Total		Count	33	60	61	154
		% of Total	21.4%	39.0%	39.6%	100.0%
Pearson chi square		P – value (0.582)				

Source: Author‟s field data (2015).

Cross-tabulation of whether or not there has been a change in the local climatic variables (rainfall, temperature and wind) and the kind or specific observed climate change showed that 92.2% of farmers have observed climate change with 37% and 35% specifying dry spells and strong winds as climate change events respectively (Table 5.1). There was no significant difference among the responses of the farmers regarding climate change and specific observed CC events ($P > 0.05$). Since majority of farmers (92.2%) have observed climate change in the study area and indicated events like strong winds, floods and dry spells, it concludes and clarify the point that farmers have knowledge about climate change and its impacts.

In addition to the events indicated earlier as representing climate change, other findings from farmers during the focus group discussions showed that locally, there are other indicators that proved to them that the climate has indeed changed. For instance, indicators such as excessive solar radiation which raises local temperatures, delayed rainfall, heavy clouds that do not produce rains and heavy windstorms were mentioned.

All these were emphasised because according to them their respective intensities and patterns have changed. Consistent with the above locally observed climatic pattern is the results from MAKESENS trend test which showed a significantly increasing trend in temperature pattern. These observable changes in patterns of climatic variables have observable impacts on crops. To the delayed rainfall in particular, all farmers during the focus group discussions in all the communities unanimously supported an observed assertion by the sub district chief farmer, that "*the normal rains have been observed to fall as early as February and sometimes March (if it delays), by which time farmers (maize, cassava and plantain farmers) start to cultivate their crops, but everything has changed since the rains now delay till May ending and even June which makes the planting time highly unpredictable. Furthermore, we have also been relying on sounds of some animals [insects (cricket or Ketekre in the local parlance) and amphibians (frog)] and sprouting of the flowers of some plants as helpful indicators for the commencement of the rainy season that prompt farmers to get prepared for cultivation. Now the timing of all these local indicators have changed and even if they occur at the expected time the rains never fall as it ought to. Indeed the climate has changed".*

5.3 CONTRIBUTION OF FARM PRACTICES TO CLIMATE CHANGE (CC)

This section looks at farmer‟s perception about farming practices that contribute to climate change. It has been highlighted in the DPSIR model which is underpinned by the Neo-Malthusian theory, that high population growth results in man‟s interaction with the environment by means of agriculture to feed the growing population thereby deteriorating the quality of the environment (deforestation and slash and burn) which contribute to climate change. The study discovered that there are various farming practices that farmers are aware of as contributing to changes in the local climate. Among the notable anthropogenic factors constituting the pressure component of the framework that contribute to climate change which was emphasised by farmers include deforestation, bush burning and slash and burn method of farming.

5.3.1 Deforestation

Table 5.2 Cross tabulation of deforestation as a contributing factor to CC

			Deforestation			Total
			Yes	No	No idea	
Observed climate change	Yes	Count	135	6	1	142
		% of Total	87.7%	3.9%	0.6%	92.2%
	No	Count	12	0	0	12
		% of Total	7.8%	0.0%	0.0%	7.8%
Total		Count	147	6	1	154
		% of Total	95.5%	3.9%	0.6%	100.0%
Pearson chi square		P – value (0.734)				

Source: Author‟s field data (2015).

Majority of farmers (87.7%) noted that deforestation (which is otherwise referred to as logging or cutting down of trees in the process of clearing the land for crop cultivation) leads to climate change. There was however no significant difference ($p > 0.05$) among the responses of the farmers (Table 5.2).

5.3.2 Slash and burn

Table 5.3 Slash and burn as a contributing factor to climate change (CC)

			Slash and burn			Total
			Yes	No	No idea	
Observed climate change	Yes	Count	132	10	0	142
		% of Total	85.7%	6.5%	0.0%	92.2%
	No	Count	11	0	1	12
		% of Total	7.1%	0.0%	0.6%	7.8%
Total		Count	143	10	1	154
		% of Total	92.9%	6.5%	0.6%	100.0%
Pearson chi square		P – value (0.002)				

Source: Author‟s field data (2015).

Majority of farmers (85.7%) affirmed that slash and burn as a farming method contributes a great deal to climate change (Table 5.3). There was a significant difference

($p < 0.05$) among the responses of farmers regarding slash and burn contributing to climate change. This means that the proportion of farmers who perceive that slash and burn as a farming practice in the study area contributes to CC differs significantly from the proportion of farmers who perceive other alternatives.

5.3.3 Bush burning

Table 5.4 Cross tabulation of bush burning as a contributing factor to CC

			Bush burning			Total
			Yes	No	No idea	
Observed climate change	Yes	Count	133	8	1	142
		% of Total	86.4%	5.2%	0.6%	92.2%
	No	Count	11	1	0	12
		% of Total	7.1%	0.6%	0.0%	7.8%
Total		Count	144	9	1	154
		% of Total	93.5%	5.8%	0.6%	100.0%
Pearson chi square		P – value (0.893)				

Source: Author"s field data (2015).

From Table 5.4, majority of farmers (86.4%) indicated that bush burning (deliberate burning the vegetation of an area either under controlled or uncontrolled supervision by farmers as ways of clearing the land for farming or other purposes) have contributed to climate change in the area. However, there was no significant difference among the proportions of the responses ($P > 0.05$). This implies that the proportion of respondents who indicated bush burning as contributing to climate change is not significantly different from the proportion of respondents who did not see bush burning as a contributing factor to climate change.

5.3.4 Fertilizer application

Table 5.5 Cross tabulation of fertilizer application as a contributing factor to CC

			Fertilizer application			Total
			Yes	No	No idea	
Observed climate change	Yes	Count	20	121	1	142
		% of Total	13.0%	78.6%	0.6%	92.2%
	No	Count	2	10	0	12

		% of Total	1.3%	6.5%	0.0%	7.8%
Total		Count	22	131	1	154
		% of Total	14.3%	85.1%	0.6%	100.0%
Pearson chi square		P – value (0.932)				

Source: Author‟s field data (2015).

Majority of farmers (78.6%), indicated that the use of fertilizer for farming purposes does not in any way contribute to climate change (Table 5.5). There was no significant difference ($p > 0.05$) among the proportions of responses by farmers.

Farming activities to a large extent contribute to the problem of climate change since it adds up to the greenhouse gas emissions. This was emphasised by Edame *et al*, (2011) when they observed that land use and land cover change through agricultural activities add up to nearly one-third of greenhouse gas emissions. It is obvious that most farmers perceive that farming practices such as slash and burn, deforestation and bush burning actually contribute to climate change based on their observations.

From the findings, majority of farmers indicated that deforestation, slash and burn and bush burning which are mostly practiced by farmers lead to climate change. These practices thus constitute the driving-forces component of the DPSIR framework. However fertilizer application according to them does not lead to climate change. This notion indicates that not all farming practices that contribute to climate change are known by farmers especially when it has some scientific underpinnings. This is because, fertilizer, right from the production point of compost making to the application point also contribute indirectly to climate change especially the inorganic fertilizers (N_2O). The production of mineral fertilizer (N P K) implies the use of energy and other materials like nitrous oxides and methane which result in emissions of GHG (Boldrin *et al.*, 2009). This means that the more farmers use fertilizers for production, the more they encourage its production. Typical GHG emissions per kg of nutrients produced in Denmark alone are 4.75–13.0 kg

CO_2-eq. for N fertilizers, 0.52–3.09 kg CO_2-eq. for P and 0.38–1.53 kg CO2-eq. for K (Boldrin *et al.*, 2009). Most practices that cause climate change usually increase the levels of CO_2 concentration in the atmosphere or decrease its removal or use by plants. Vermeulen *et al* (2012) had also observed that food systems contribute 19%– 29% of global anthropogenic greenhouse gas (GHG) emissions, releasing 9,800–16,900 megatonnes of carbon dioxide equivalent ($MtCO_2$-eq) in 2008. Agricultural production, including indirect emissions associated with land-cover change, contributes 80%–86% of total food system emissions, with significant regional variation (Vermeulen *et al.*, 2012).

5.4 PERCEPTIONS OF FARMERS ON EFFECTS OF CHANGES IN RAINFALL PATTERN ON OUTPUT OF CROPS

Table 5.6 Cross tabulation of point of effect of changes in rainfall pattern on crops

			Changes in rainfall pattern		Total
			Yes	No	
Point of effect	land preparation	Count	15	0	15
		% of Total	9.7%	0.0%	9.7%
	germination and growth	Count	26	2	28
		% of Total	16.9%	1.3%	18.2%
	fruit development	Count	64	2	66
		% of Total	41.6%	1.3%	42.9%
	Maturity	Count	41	4	45
		% of Total	26.6%	2.6%	29.2%
Total		Count	146	8	154
		% of Total	94.8%	5.2%	100.0%
Pearson chi square		P – value (0.405)			

Source: Author‟s field data (2015).

Cross-tabulation on point (or stage in the production process) of effect of changes in rainfall pattern on crops showed that 94.8% of farmers observed changes in rainfall pattern and how it affects crop production with 41.6% indicating its impact on fruit development stage (Table 5.6). There was however no significant difference among the responses on the point of effect ($p > 0.05$). This implies that changes in rainfall pattern equally affects land preparation, germination and growth, and fruit maturity to similar extents.

Changes in climatic variables such as rainfall, temperature and windstorm may invariably affect the output of crops. The impact may affect the crops at any stage of the production process right from the land preparation to maturity stage of crops. From table 5.6, most farmers indicated that changes in rainfall pattern affects crop production (especially maize and plantain) negatively especially at fruit development stage. Most farmers linked the effects of changes in rainfall pattern to at least one stage of crop production process. It became clear from the Focus Group Discussion (FGD) that variability or changes in rainfall pattern in the form of delayed rainfall affect crops especially maize, cassava and plantain at their critical stage of developing fruits thereby resulting in drastic reduction of output which is a major function of food security.

As an affirmation, the impact of the delayed rains on plantain and maize outputs was further stressed by one of the farmers which met a unanimous support from all others during the FGD. He remarked "*my son, this your climate change has really caused us great harm because, the delayed rains of recent years result in development of small sizes of plantain fruits to the extent that even a little child can easily lift it, meanwhile this wasn't so some years past. I can say confidently that this can never be attributed to soil infertility or other factors, because the soil is fertile enough since we allow land to fallow for years. Sometimes too, when the rain ceases (for about a month or more) after few days of early showers, it becomes disastrous to the maize crop especially after germination since it doesn't get enough water to develop and mature the corn in time*". A similar observation was made by Siana *et al.* (2013), concerning how unpredictable and unreliable rainfall has become a threat to agricultural activities. During the field observation an ideal maize farm at its critical and vulnerable stage (fruit development stage) was shown to us, that all things being equal, the maize will produce the required quantity of corn (see Plate 5.1). However that stage or point in the life span of maize crops is so critical, that it is highly vulnerable to instances of delayed rains or outright rain failure, and since fruits are developing at that stage, it can cause deficiency to crop yield and a reduction in output or complete loss of productivity.

Again during extreme weather events such as strong winds and floods, a whole maize and or plantain farms are pulled down leading to complete loss of the entire farm during the fruit development stage. It was explained that the crops at that stage become heavier in weight because of the fruits they bear and so easily fall down during such extreme weather events as windstorm. When this happens the yield is greatly reduced or leads to total loss.

Plate 5.1 Maize farm at its critical and most vulnerable stage in developing fruits (corn); a shot from a farmer's farm at Awaso-Asempanaye community.

Source: Field survey (2015)

It is worth noting from the regression results in chapter four that the overall impact of rainfall on maize and cassava output over the 31 year period was negative even though not significant. Farmers have also observed a reduction in output of maize and plantain due to extreme weather events like windstorms which mostly accompany heavy rainfalls.‟ Perceptions of farmers connote more of a great loss, but their observations are informed from variability of climatic elements‟ point of view rather than a change of climatic elements over the 31 year period. With this food security per this study is highly threatened since at every point in time such extreme weather events could result in output loss if appropriate adaptation measures are not put in place.

The trend analysis in chapter four also showed a non-significant monotonic increasing trend in rainfall pattern over the period which is also consistent with the coefficient of variation of the rainfall data set. In like manner, the output of maize and plantain were highly elastic to changes in rainfall amount and if farmers also noticed a negative impact on maize output, it means there is consistency in the findings from both the secondary data and the empirical primary data.

5.5 PERCEPTIONS OF FARMERS ON THE EFFECTS OF CHANGES IN TEMPERATURE PATTERN ON CROP PRODUCTION

Table 5.7 Cross tabulation of point of effect of changes in temperature on crop

			Point of effect				Total
			land preparation	germination and growth	fruit development	Maturity	
Change in temperature affect Output	Yes	Count	15	26	61	44	146
		% of Total	9.7%	16.9%	39.6%	28.6%	94.8%
	No	Count	0	2	5	1	8
		% of Total	0.0%	1.3%	3.2%	0.6%	5.2%
Total		Count	15	28	66	45	154
		% of Total	9.7%	18.2%	42.9%	29.2%	100.0%
Pearson chi square			P – value (0.457)				

Source: Author‟s field data (2015).

Majority of farmers (94.8%) indicated that change in temperature affects output with 39.6% indicating its effect on fruit development stage (Table 5.7). There was no significant difference among the responses regarding the point of effect of change in temperature ($p > 0.05$). This implies that farmers were able to acknowledge that change in temperature affected land preparation, germination and growth, fruit development and maturity.

Majority of the farmers indicated that changes in temperature affect crop yield especially during the fruit development stage. Farmers also acknowledged the impact of changes in temperature on land preparation, germination and maturation stages of crop production. Emphases from the FGD has it that except for mulching (an adaptation measure) that shields the tubers of cassava from the high intensity of the incoming solar radiation (high temperatures), in most cases the tubers become heated up in the soil and get rotten. A doubling effect is observed in the rate of photosynthesis when temperature changes by 10^0C help to increase crop output, however excessive temperature as in the case observed by farmers inhibits enzyme activities thereby reducing productivity.

Another observation made by most of the farmers over the years which was raised during the FGD was that the high temperatures lead to extinction of most native plants and weeds and lead to proliferation of strange weeds (Plate 5.2) that seem to colonize the land and affect the thriving of the crops. The two most troublesome strange weeds that were identified are called "*Ananse Tumi* and *Onyame Nwui a Menwui*" in the local parlance, which means by translation "*the power of the spider* and *I live as long as God lives or until God dies I will never die*" respectively. These weeds are both creeping plants (see Plate 5.2) and attack both the bare land and coil around the maize, cassava and plantain plants to climb in order to pull them down. Their proliferation is such that once they emerge, they will continue to flourish whether rainy season or dry season and they don"t die even after they are cleared. When this happens, the weeds usually take over the farms since farmers find it difficult to control and leads to deficiencies like stunted growth of crops and poor yield in terms of quality and quantity.

This is directly consistent with the findings of the OLS (regression) model in chapter four, since the output of all the crops (maize, cassava and plantain) were negatively impacted by the monotonic increasing temperature trend. A consistency in the sense that, the results of the Sen‟s slope of the trend analysis of rainfall and temperature revealed a highly significant monotonic increasing trend. The impact of such increasingly high temperatures also showed a significant negative impact on maize output. Farmers have also observed a decrease in output of most crops due to extreme events like excessively high temperatures and dry spells. This has negative implication on food security if appropriate measures are not put in place to adapt.

Plate 5.2 Strange creeping plants induced by extremely high temperatures

(a) Bare land showing extinction of native weeds due to excessively high temperature.
(b) *Ananse tumi* weed attacks cassava plant by coiling around it and break it down.
(c) *Onyame nwui a menwui*" weeds in their uncleared state on the field.
(d) A cleared " *Onyame nwui a menwui*" weed
(e) *Ananse tumi* weed attacks cassava plant

Source: Author‟s field work (2015)

5.6 FARMERS ADAPTIVE STRATEGIES AGAINST CLIMATE CHANGE

This section explores the various adaptation measures employed by farmers in the study area to combat climate change impact on their crops. Adaptation measures to CC which involves the various methods put in place to withstand or reduce the potential impact of climate change, become necessary when the magnitude of the impact of climate change appears significant to man. As highlighted by the "response" component in the DPSIR framework, when poor farming practices such as slash and burn and deforestation compound the problem of CC, the resulting impacts on crops are felt directly by farmers and so they have to devise means to adapt. A cross tabulation of dichotomous "yes and no" questions on the various adaptation measures to climate change were presented to farmers to indicate which amongst the options were mostly adopted. These included mulching, crop diversification, diversification to non-farm activities, and use of agrochemicals, mixed cropping, changing crop variety, changing farm location and the practice of irrigation farming. The results of the field survey revealed that the most preferred adaptation measures against the devastating impact of CC on their crops includes mulching, mixed cropping, change of crop variety, use of agro chemicals and crop diversification.

Table 5.8 Adaptation measures against CC

ADAPTATION MEASURES	YES (count)	%	NO (count)	%	Chi-Square
Mulching	128	83.7%	25	16.3%	0.439
Crop diversification	137	89.0%	17	11.0%	0.538
Diversification to non-farm activities	5	3.2%	149	96.8%	0.749
Use of agrochemicals	57	37.0%	97	63.0%	0.894
Mixed cropping	152	98.7%	2	1.3%	0.841
Changing crop variety	132	86.3%	21	13.7%	0.485
Changing farm location	32	20.8%	122	79.2%	0.588
Practice of irrigation farming	18	11.7%	136	88.3%	0.525

Source: Author"s field data (2015)

Farmers" choice of adaptation measures against CC in order of preference From Table 5.8 indicated that 98.7% of the respondents practiced mixed cropping as an adaptation measure, 89.0% diversify their crops in order to cope with the changing climate, 86.3% also adapted by means of changing the varieties of their crops and 83.7% also practiced mulching as adaptation measure. The use of agrochemicals was adopted by only 37.0 %

of the respondents as means of adapting to climate change. The least measure adopted by farmers to cope with CC was diversification to non-farm activities since only 5 (3.2%) respondents opted for that option. The Chi-Square test results in all cases from Table 5.8 shows that there is no significant difference ($P>0.05$) among the responses of farmers. This implies that the proportion of farmers who chose the various adaptation measures in the study area does not significantly differs from the proportion of farmers who did not choose the other adaptation measures.

Cross tabulation of specific adaptation measures adopted against climate change to prevent crop failure indicated that mulching, mixed cropping, crop diversification and changing crop variety were mainly used by farmers. The choice of these adaptation measures was informed by farmer"s years of farming experience in crop production. The farmers maintained the notion that after exploring a number of possible adaptation measures, they concluded that the above mentioned adaptation measures proved effective hence the choice. This observation is consistent with the studies of Obayelu *et al.* (2014), Onoh *et al*. (2014), Ndamani and Watanabe, (2015), Ifeanyi-obi and Nnadi, (2014), and Uddin *et al.* (2014). Mulching which involves the use of dead organic materials to cover the surface of the soil in order to conserve soil moisture content was very popular adaptation strategy which most farmers adopted. This serves both as soil and water conservation practice thus improving soil productivity. Mulching as an adaptation measure to cope with the impact of climate change was emphasised in the findings of a study by Onoh *et al.* (2014) where it was observed that farmers in Imo State of Nigeria used mulching as the main measure against CC. Mixed cropping which involves planting of different kinds of crops on the same piece of land was highlighted by 98.7% of farmers as the most preferred adaptation measure against climate change. By mixed cropping, they indicated that the dominant crop combination at a time on a piece of land included cassava, plantain, cocoyam, maize, some vegetables as well as some cash crops like cocoa or oil palm. Again, this finding is consistent with the studies of Onoh *et al*.

(2014), Obayelu *et al*. (2014) and Uddin *et al*. (2014). Also from the Focus Group Discussions (FGD), it was discovered that mixed cropping as an adaptation measure provided farmers with crop yield even in situations where there were failures of one kind of crop or the other due to climate change. Quoting directly from a female respondent at Tanoso; "*We have used mixed cropping for years and have realized that it is the best adaptation measure so far. This is because whenever there is extreme climatic event such dry spells, wind storm or delayed rains, and some of the crops are affected negatively, others still remain unaffected thereby providing yield which mono cropping would not give*."

In like manner, as crop diversification and changing crop variety (using different variety or species of the same crop either because of differences in gestation periods or returns) were adopted by majority of respondents as measures to cope with climate change, Uddin *et al*. (2014) also identified crop diversification and changing crop variety as measures adopted by farmers in Bangladesh. Crop diversification involves addition of new crops or substituting new crops for others on the same farm land for different returns from the value-added. Ndamani and Watanabe, (2015), indicated that farmers in Northern Ghana use crop diversification as an adaptation measure to combat the impact of climate change on crops. These measures were found to be effective by farmers based on their experience to select an adaptation measure against climate change induced crop failure.

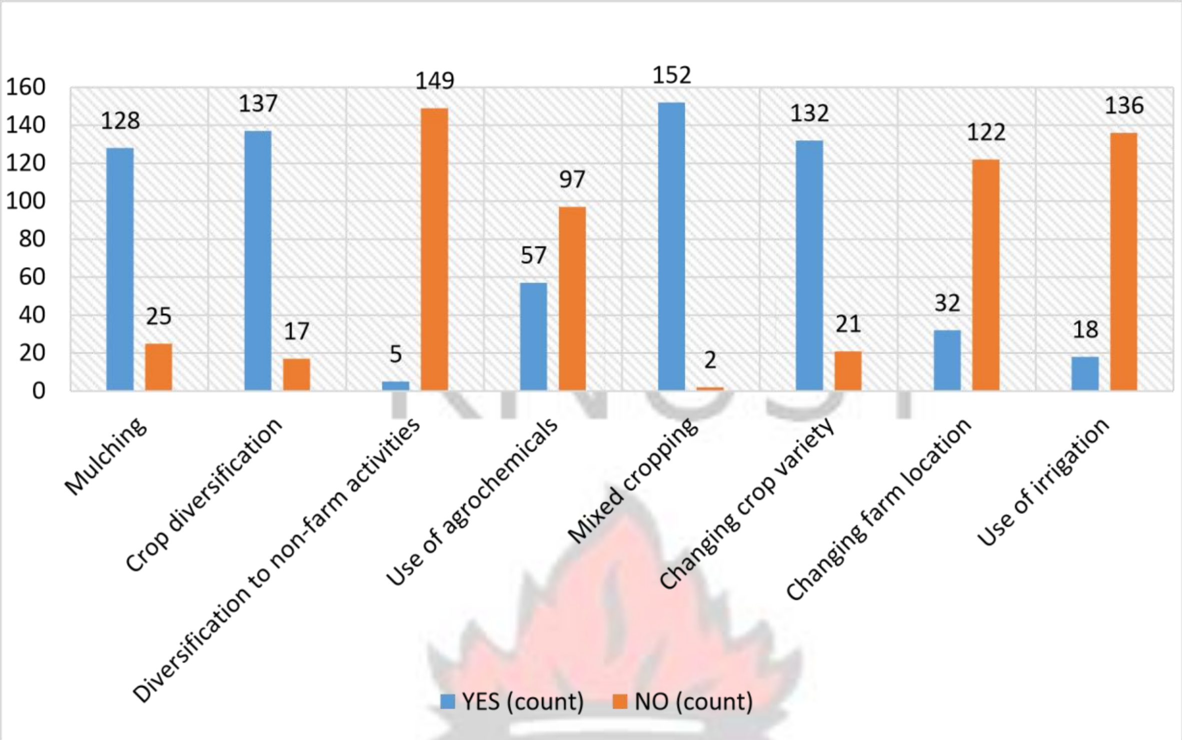
Contrary to the preferred measures adopted by farmers against climate change, diversification to non-farm activity, irrigation practices, use of agrochemicals and changing farm location were least adopted as adaptation strategies. This is also consistent with the observations of Ndambiri *et al*. (2013) but contrary to the findings of Uddin *et al*.

(2014) which rated irrigation as the most adopted measure in coastal areas of Bangladesh. Again, it was highlighted by farmers during focus group discussions that they knew the importance of irrigation and use of agrochemicals such as fertilizers, insecticides and herbicides in crop production, but their problem of not adopting such measures was due to the high cost involved which they could not afford.

In a nutshell, the dichotomous “yes and no” responses of farmers on specific adaptation measures against climate change as shown in (Figure 5.1) indicated that most farmers accented to using mixed cropping, crop diversification, changing crop variety and mulching as measures adopted against crop failure. On the other hand, measures such as diversification to non-farm activities, use of agrochemicals, irrigation and changing farm location were least adopted to cope with climate change.

In addition however, it was also discovered during the focus group discussions that locally, farmers use some other means to cope with the destructive effects of extreme climatic events. It was observed that during situations of windstorm or heavy winds, several acreages of maize, plantain and cassava farms are pulled down but the farmers are able to support their crops with sticks and palm fronds. According to them, they drive palm fronds and such other strong sticks deep into the ground and make it firm after which surrounding maize plants that were pulled down are raised and tied to the sticks. Some also said they do nothing to cope rather they look up to God.

Figure 5.1 Summary on measures adopted by farmers against CC to prevent crop failure



Source: Author‟s Field Data (2015).

5.7 DETERMINANTS OF ADAPTATION TO CC BY THE VARIOUS COMMUNITIES

This sub-section considers the factors that determine the various adaptation measures adopted by farmers against climate change (CC) within the various communities. As to whether or not factors such as community based governance, availability of resources, education in a form of information on better adaptation choices, years of farming experience, land tenure status and extension service support influence their choice of adaptation measures at their communities. By cross tabulating the study communities (Awaso-Asempanaye, S/Bekwai, Tanoso, Kunkumso, Wenchi and Hwenampori) against specific determinants a more spatial variation regarding what is happening at different communities have been unearth. These have been presented in the tables in this sub-section. In addition, a factor that was most highlighted as determining their choice of adaptation at the various communities was further cross tabulated with the level to education of respondents to elicit the nuances that may explain such factors better.

Table 5.9 Community based governance as a determinant of adaptation against CC in the various communities.

			Communities						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Community based Governance	Yes	Count	1	0	0	0	0	0	1
		% of Total	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
	No	Count	33	64	15	10	14	17	153
		% of Total	21.4%	41.6%	9.7%	6.5%	9.1%	11.0%	99.4%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.615									

Source: Author‟s field data (2015).

It is observed from Table 5.9 that only a farmer from Awaso-Asempanaye did adapt to CC based on community based governance. Community based governance involves locally instituted organisation with appointed and trained leaders who offer guidance to farmers on proper farming methods and practices. There was however no significant (P > 0.05) relationship between the responses of the famers.

Table 5.10: Resource availability as a determinant of adaptation by communities.

			Community						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Availability of resource	Yes	Count	4	0	0	0	0	0	4
		% of Total	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%
	No	Count	30	64	15	10	14	17	150
		% of Total	19.5%	41.6%	9.7%	6.5%	9.1%	11.0%	97.4%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.013									

Source: Author‟s field data (2015).

From Table 5.10, only 4 respondents out of 34 farmers from Awaso-Asempanaye indicated that they adapted to CC based on available resources such as variety of crop seedlings, money to purchase agrochemicals as well other local resources such as strong sticks for supporting crops during rainstorms etc. About 150 respondents from the remaining five communities including 30 out of the 34 respondents from AwasoAsempanaye did not adapt to CC based on resource availability. There was a significant relationship (P < 0.05) among the responses of farmers.

Table 5.11 Education through information acquired as a determinant of adaptation by communities.

			Communities						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Education	Yes	Count	13	10	0	0	0	0	23
		% of Total	8.4%	6.5%	0.0%	0.0%	0.0%	0.0%	14.9%
	No	Count	21	54	15	10	14	17	131
		% of Total	13.6%	35.1%	9.7%	6.5%	9.1%	11.0%	85.1%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.000									

Source: Author‟s field data (2015).

Majority (85.1%) of the farmers did not adapt to climate change based on any special information given them in a form of education. However 14.9% of the farmers being (8.4%) and (6.5%) from Awaso-Asempanaye and Sefwi Bekwai respectively indicated that they adapted to CC based on education given to them by either extension officers or any other source (Table 5.11). The relationship that exist among the responses of farmers was highly significant (P < 0.05).

Table 5.12: Land tenure status as a determinant of adaptation to CC by communities.

			Community						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Land tenure status	Yes	Count	1	0	0	0	0	0	1
		% of Total	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
	No	Count	33	64	15	10	14	17	153
		% of Total	21.4%	41.6%	9.7%	6.5%	9.1%	11.0%	99.4%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.615									

Source: Author‟s field data (2015).

When farmers were asked whether or not ownership of their farmlands was a determining factor to adapt to climate change, only 1 out of 34 respondents from AwasoAsempanaye said yes. Majority 153(99.4%) from the remaining five communities including those from Awaso-Asempanaye affirmed that they did not adapt to climate change due to land tenure status (Table 5.12). even though follow-up inquiries discovered that majority were owner occupiers with the minority being tenants (i.e. operating on the basis of share cropping). There was a small association among the responses of farmers which did not also vary significantly (P > 0.05). In contrast to this finding is a study conducted in Egypt by Dinar *et al*. (2008) cited in Smith and Malik (2012) where farmers working on rented lands were found to be less likely to adapt to climate change than those who own lands, presumably because owners receive the benefits of land improvements, or at least a larger share of them.

Table 5.13: Years of farming experienced as a determinant of adaptation to CC by communities.

			Community						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Experience	Yes	Count	32	63	15	10	14	17	151
		% of Total	20.8%	40.9%	9.7%	6.5%	9.1%	11.0%	98.1%
	No	Count	2	1	0	0	0	0	3
		% of Total	1.3%	0.6%	0.0%	0.0%	0.0%	0.0%	1.9%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.561									

Source: Author"s field data (2015).

With regard to experience or years of farming experience as a determining factor to adapt to climate change, majority (98.1%) of the respondents indicated that indeed, whether or not they would adapt to CC depends largely on years of farming experience since to them, the climate keeps changing. this finding is consistent with a study conducted in Kenya by Ndambiri *et al.* (2013) where majority (74%) of farmers who adapted to climate change had farming experience of more than 10 years in comparison to 11% of farmers who had low experience of about 10 years and below. At AwasoAsempanaye community, out of 34 respondents, 32 claimed to have adapted to climate change based on years of farming experience and only 2 respondents did not adapt to CC due to years of farming experience. A similar pattern was observed at S/Bekwai where out of 64 respondents, 63 had adapted to CC based on years of farming experience and only one person indicated that his adaptation to CC was not determined by experience.

There was no significant difference among the responses of farmers (P > 0.05).

Table 5. 14: How respondents' level of education affect their choice of "years of farming experience" as a determinant of adaptation to CC in the area.

			Highest education level					Total
			Primary	Middle school	Secondary school	Tertiary	No formal education	
Years of farming Experience	Yes	Count	38	29	15	16	53	151
		% of Total	24.7%	18.8%	9.7%	10.4%	34.4%	98.1%
	No	Count	2	1	0	0	0	3
		% of Total	1.3%	0.6%	0.0%	0.0%	0.0%	1.9%
Total		Count	40	30	15	16	53	154
		% of Total	26.0%	19.5%	9.7%	10.4%	34.4%	100.0%
Pearson Chi-Square = 0.417								

Source: Author"s field data (2015).

Table 5.14 shows that out of 151(98.1%) respondents who had adapted to CC based on years of farming experience, 53(34.4%) had no formal education, 38(24.7%) had primary education, 29(18.8%) had middle school certificate, 15(9.7%) had secondary education and the remaining 16(10.4%) had tertiary education. On the other hand, the remaining 3 respondents who did not adapt to climate change based on years of farming experience constitute only 2 with primary education and one person with middle school certificate (Table 5.14). This contrasts the findings of a study conducted in Kenya by Ndambiri *et al.* (2013) where majority (63%) of farmers who adapted in various ways to changes in temperature and precipitation had reached post primary education level compared to those who had up to primary level (22%).

By inference, it can be deduced that since respondents with no formal education formed the majority among those whose adaptation strategy against CC was determined by their years of working experience, the role of formal education (highest educational attainment level) in the choice of adaptation measure against CC is not paramount in the study area. Implying that just as those with formal education (from the primary level through to the tertiary level) chose adaptation measure largely based on years of farming experience, so are those with no formal education. This therefore makes it imperative to consider the judgements of farmers with more years of farming experience even without formal education very important in the same way as those with formal education.

Table 5.15: Extension service as a determinant of adaptation to CC by communities.

			Community						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Extension Services	Yes	Count	3	2	0	0	1	6	12
		% of Total	1.9%	1.3%	0.0%	0.0%	0.6%	3.9%	7.8%
	No	Count	31	62	15	10	13	11	142
		% of Total	20.1%	40.3%	9.7%	6.5%	8.4%	7.1%	92.2%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.001									

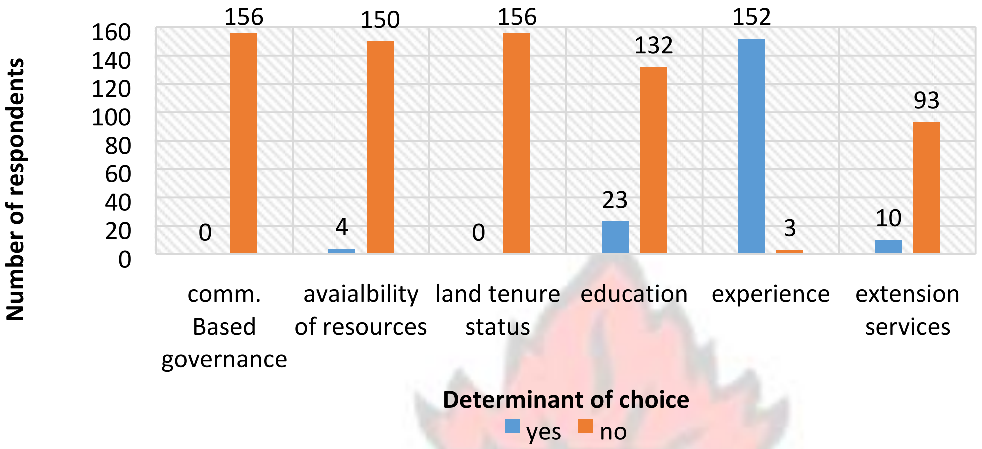
Source: Author"s field data (2015).

Extension services was not seen as a reason for adaptation by majority of the respondents (92.2%). This is because out of the total population, only 12 respondents representing 7.8% from all the study communities adapted to CC based on services provided by agricultural extension agents (Table 5.15). However, at AwasoAsempanaye, out of a total of 34 respondents, 3 adapted to CC due to assistance from agricultural extension officers. In like manner, 2 out of a total of 64 respondents from S/Bekwai also adapted to CC by depending on services provided by agricultural extension officers. The relationship between responses of farmers was highly significant ($P < 0.05$).

Judging from the above factors that determine farmers‟ adaptation measures, it is observed in most cases that few respondents with contradictory views from the views of the majority came from Sefwi Bekwai and or Awaso-Asempanaye. Thus these few respondents did not adapt to climate change based on the determinants which influenced majority of the respondents. By inference and per the characteristics of the study communities highlighted in chapter three sub-section (3.2.5), it can be said that the respondents who did not choose adaptation measure based on farmers‟ years of farming experience but chose availability of resources may be engaged in other lucrative secondary occupation that afforded them enough resources to adapt to CC. This is so because from the findings (from the focus group discussion), most respondents from Sefwi Bekwai and Awaso-Asempanaye in addition to their primary occupation (farming) also undertake other secondary activities such as trading (during the periodic marketing at Sefwi Bekwai) and mining (at Awaso-Asempanaye bauxite company). This can be substantiated from the viewpoint that so long as other communities (namely Tanoso, Kunkumso and Wenchi) which are predominantly into crop production attributed their adaptation measures largely to years of farming experience and not resource availability or community based governance, then the secondary activities at Sefwi Bekwai and Awaso-Asempanaye have influence on the determinants of adaptation measure by the minority respondents.

Also, the fact that majority of the respondents from all the study communities apparently adapted to climate change based on their years of farming experience perhaps explains the importance of experience in adaptation to CC in the study area. This observation is consistent with a study by Dinar *et al*. (2008) cited in Smith and Malik (2012) whose study of the adaptation to climate change in low-income countries, observed that farmers with more experience and better-education (well informed) were found to be more likely to undertake adaptation measure against climate change at the individual level, other things being equal.

Figure 5.2 Summary of determinants of adaptation measures



Source: Author‟s Field Data (2015).

Measures adopted against climate change by farmers in the area was based mainly on years of farming experience as 96.1% accented to choosing an adaptive measure by experience. Majority of farmers (> 80%) did not depend on community based governance, availability of resource, land tenure system, extension service and education to choose an adaptive measure against climate change. There was no significant difference between the determinants of adaptation and adaptive measure chosen (p > 0.05). Figure 5.2 gives a graphical summary (in counts) of the major determinants of adaptation to and coping strategies chosen against climate change.

5.8 EFFECTIVENESS OF ADAPTATION MEASURES TO CC AT VARIOUS COMMUNITIES

This section considers how effective the various adaptation measures farmers adopted against climate change have been at the various communities. Whereas in some communities adaptation measures were observed to be very effective, other communities observed moderate effectiveness or no effect.

Table 5.16: Effectiveness of adaptation measures by communities.

			Community						Total
			Awaso-Asempanaye	S/Bekwai	Tanoso	Kunkumso	Wenchi	Hwenampori	
Effectiveness of Adaptation Measures	Very effective	Count	30	16	15	7	14	2	84
		% of Total	19.5%	10.4%	9.7%	4.5%	9.1%	1.3%	54.5%
	Moderate	Count	4	46	0	3	0	15	68
		% of Total	2.6%	29.9%	0.0%	1.9%	0.0%	9.7%	44.2%
	No effect	Count	0	2	0	0	0	0	2
		% of Total	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	1.3%
Total		Count	34	64	15	10	14	17	154
		% of Total	22.1%	41.6%	9.7%	6.5%	9.1%	11.0%	100.0%
Pearson Chi-Square = 0.000									

Source: Author"s field data (2015).

About 84(54.5%) farmers affirmed that their adaptation measures against climate change was very effective, 68(44.2%) also affirmed that theirs were moderately effective and only 2(1.3%) indicated that adaptation measures in which ever form was not effective (Table 5.16). There was high significant difference (P < 0.05) between responses of farmers concerning the effectiveness of climate change adaptation strategies.

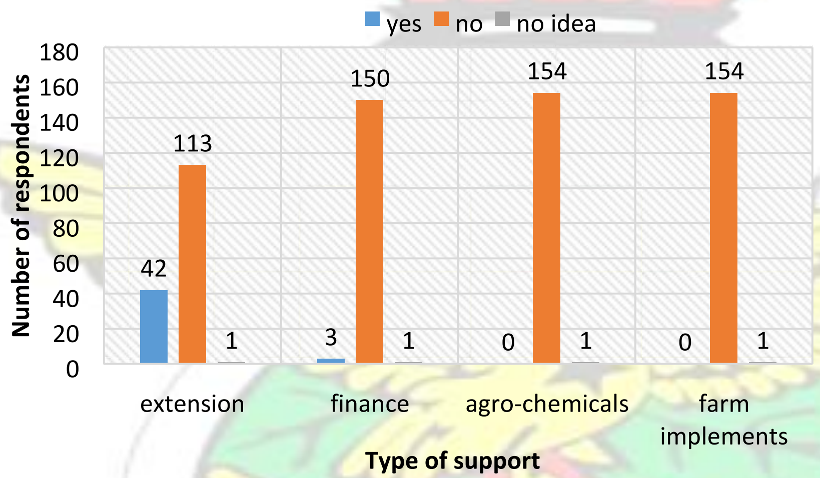
It is observed from Table 5.16, that to the farmers, the various adaptation measures which included mixed cropping, changing crop variety, crop diversification and mulching were either very effective or moderately effective. When respondents were probed on the basis for considering adaptation measures as very effective or moderately effective, they attributed a discernible increase in output of crops in current year, compared with previous years to effective adaptation measures whereas a slight increase or no change in output was also attributed to a moderately effective adaptation measures. Furthermore, through a comparison of output accrued from cultivation before and after a particular adaptive measure was adopted can determine whether a particular adaptation measure has been effective or not.

If their reasons are justifiable, then output levels of crops at Sefwi Bekwai and

Hwenampori have not witnessed any significant improvement. And that can partly be explained from the perspective that even though farming is the primary occupation of all the respondents at Sefwi Bekwai and Hwenampori, however, some of them engaged in secondary occupations such as trading or bauxite mining as in the case of AwasoAsempanaye. With this, farmers have divided attention and may sacrifice time meant for proper adaptation strategies for other activities which may render adaptation strategies against CC impacts on crops not to yield the needed effectiveness.

5.9 STRENGTHS AND WEAKNESSES OF INSTITUTIONAL MITIGATION STRATEGIES

Figure 5.3 Institutional / government support to cope with CC



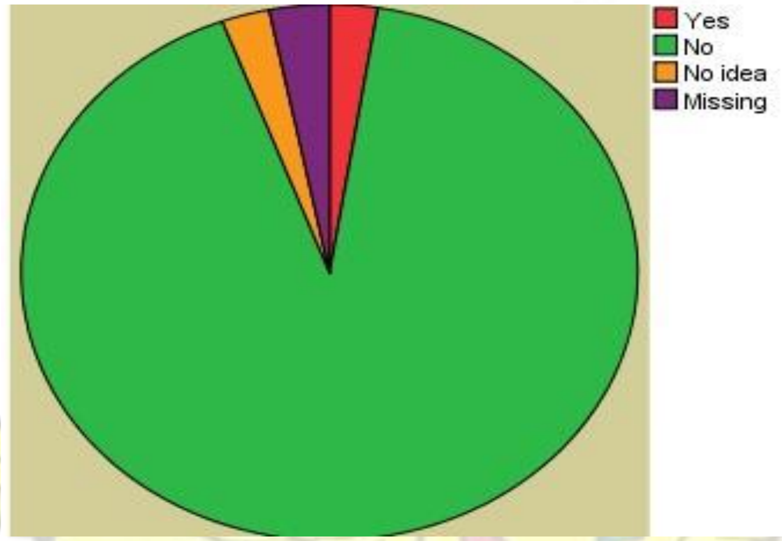
Source: Author‟s Field Data (2015).

From Figure 5.3, it is observed that institutional mitigation measures or government support to assist farmers to adapt to CC in the form of finance, use of agro chemicals and farm implements were not received by farmers. The presence of extension services in the communities which 42 respondents out of 154 responded yes to, were even non-functional according to them.

From cross tabulation results (appendix N, and Figure 5.4), majority of farmers affirmed that they do not receive government support in any form against climate change.

Extension services, farm implements, agrochemicals and financial assistance were not received as a support by majority of farmers (> 90%) from the government. There was no significant difference among the responses of farmers in receiving government support against climate change. There was however a small association among the responses of the farmers. This implies that the responses of the farmers were independent from one another.

Figure 5.4. Government support to adaptation



Source: Author‟s Field Data (2015).

During the focus group discussions at the various communities notably, Tanoso, Hwenampori, Awaso and Wenchi, when issues on the presence of agricultural extension officers in the farming communities and visitations by GMA officers (to educate farmers on the periodic expected weather conditions and what farmers should guard against) were raised, they simply gave a unanimous expressions of disappointment in the existence of such institutions in the country. They highlighted the fact that such institutions do not function even though they may exist. They further stressed that for the past 10 or more years, they have not received any form of support (e.g. education, financial aid and or agro chemicals) from any institution and that those officers assigned to visit their communities to educate farmers on measures to adopt against adverse effects of climate change never come.

5.10 CONSTRAINTS TO ADAPTATION

Table 5.17: Constraints to adaptation

CONSTRAINTS	YES (Count)	%	NO (Count)	%	Chi-Square
Lack of knowledge on proper adaptation	153	99.4%	1	0.6%	0.888
Limited land to expand farm size	140	90.9%	14	9.1%	0.580
High cost of agricultural inputs	152	98.7%	2	1.3%	0.841
Lack of access to climate information	148	96.1%	6	3.9%	0.725
Lack of access to water for irrigation	151	98.1%	3	1.9%	0.805
Financial constraints	152	98.7%	2	1.3%	0.000***

Source: Author‟s field data (2015).

From Table 5.17, majority of the farmers (99.4%) indicated that they don‟t have much knowledge about deliberate and proper adaptation measures to climate change. This is because they have considered the prevailing adaptation strategies they adopt as just a routine way of carrying out their activities. They could do better and improve tremendously should they know that they have actually been adapting to climate change by virtue of those measures.

Again, the cross tabulation results shows that majority of farmers (90.9%) have emphasised limited land area to expand their farm sizes as a major constraint to their ability to adapt to climate change impacts (Table 5.17). In this regard farmers would wish to expand their land size or relocate to different piece of land for cultivation but the large expanse of land to do so is non-existent. This is a major challenge because when we recall from the regression results in chapter four (Tables 4.2, 4.3 and 4.4), it is observed that an increase in the size of the land area (LA) has a significant impact on the quantity produced of a particular staple crop all things being equal. Farmers are most often left with no other option than to continue tilling the same land area over and again even in the case of extreme climatic event such as delayed rains. Whenever there was a delay in rainfall timing, farmers preferred to relocate to other areas close to rivers and other water bodies so that they could manually use the source of water for irrigation but such areas have not been available to them due to limited land sizes.

High cost of agricultural inputs was also emphasised by respondents (98.7%) as a constraint to adapt to climate change and its impacts on their activities. Agricultural inputs such as agrochemicals, seedlings of improved crop variety (as in the case of maize and cassava) and other farm implements that could enhance their activities were considered too expensive to acquire to combat climate change.

In addition, most of the farmers (98.1%) observed that lack of access to water was also a serious challenge that hindered adaptation to climate change. This response was again supported unanimously by the farmers during the Focus Group Discussions (FGD) at Awaso-Asempanaye, Tanoso, Kunkumso and Wenchi, that almost all the rivers and streams within the area that could have been used for irrigation manually have dried up due to high temperatures and excessive evaporation. They also emphasised that the illegal mining activities in the area have accelerated the rate of water loss. They said the rivers have all been turned to mud by the artisanal mining activities so they cannot be used for the purpose of irrigation. Farmers therefore rely solely on rainfall for farming activities and this has been very unreliable.

Finally, lack of access to climate information and financial constraints were two other most serious challenges that were emphasised by majority of the respondents (96.1%) and (98.7%) respectively as obstacles to adaptation measures against climate change (Table 5.17). The study discovered that the ability to choose any adaptation measure against climate change in the area depends largely on finances which was also stressed by farmers during the FGD to be non-existent in whatever form. They did not have access to loans or any other credit facilities that could afford them the means to purchase agrochemicals or any improved seed variety that could withstand harsh climatic conditions. The study also discovered from the FGD that information on micro-weather conditions in the area that could assist farmers to make informed decisions regarding adaptation measures against climate change from the local meteorological agencies have not been available.

In conclusion, the results on the farming practices that contribute to climate change revealed that certain farming practices such as deforestation, slash and burn as well as bush burning really contribute to climate change. Siana *et al* (2013) emphasised that the anthropogenic contributions to climate change is potentially causing increased food insecurity globally; industrialization, modern agricultural practices and the need to produce for the market without thinking about the environmental sustainability has had disastrous impact on agriculture. These constitute the drivers, the pressures and the change of state of the environment due to agricultural activities in the DFPSIR framework.

Climate change phenomenon such as unpredictable rainfall pattern has been observed by Siana *et al.* (2013) that it results in greater uncertainty among farmers and their traditional agricultural knowledge and coping strategies. The phenomena has thus had immediate negative impact on food production and distribution in all parts of the world. This is evident in the results generated from the regression and cross tabulation on impact of changes in rainfall and temperature patterns on output levels of the selected crops (Tables 5.6 and 5.7).

Attempts to avert the impact of climate change on crop production have been the various adaptation measure highlighted above. These attempts by farmers or institutions to offset CC impacts on crops form the response component of the DFPSIR framework that drives the tenets of this work.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 SUMMARY

This chapter looks at summary of major findings, policy recommendations and concludes the whole study. The phenomenon of climate change and its impacts on food security has attracted attention of global research. The approaches to which have been narrowly explored and thus have hindered the elucidation of actual impacts quantitatively as in the case of specific variables against specific crops. It is against this background that the study used the DPSIR model and the OLS model to examine the actual impacts of climatic variables like rainfall and temperature on outputs of selected staple crops (maize, cassava and plantain).

More specifically the study was guided by the following objectives which also highlights the essential components of the DPSIR framework adopted to anchor the study: first, the impacts of climate change on output of selected crops have been looked at. Again perceived farming practices that contribute to climate change and local indicators of climate change have also been considered. Finally various adaptation strategies and institutional mitigation measures have thoroughly been looked at.

In order to achieve the objectives of the study, 156 household heads were selected from 6 communities and administered with questionnaires whereas 75 others were engaged in extensive discussions concerning the subject. Again, 31 years data set for climate variables (mean annual rainfall and temperature) and that of output of selected crops (maize, cassava and plantain) as well as land area cultivated were regressed to determine the impacts of rainfall, temperature and land area on the outputs of maize, cassava and rainfall.

Microsoft excel and Eviews software were used to perform the multiple regression analysis of rainfall, temperature and land area impacts on maize, cassava and plantain. Again, the IBM SPSS Version 20 statistical package was used to analyse the primary data. That is cross tabulating the perceptions of farmers on climate change and observed impacts at specific stage as well as adaptation measures to climate change. The major findings of the study are summarized below.

6.1.1 Contribution of farming practices to climate change (CC)

Farming activities to some extent contribute to the problem of CC. This is so because majority of farmers affirmed their perception on that, by indicating that deforestation, slash and burn and bush burning which are mostly practiced by local farmers lead to climate change. This is consistent with the findings of Edame *et al.* (2011) on causes of climate change that land use and land cover changes through agricultural activities add to nearly one third of greenhouse gas emissions.

6.1.2 Perceived impacts of changes in rainfall pattern and temperature on crop production

Output of maize, cassava and plantain have all proved to be negatively impacted by changes in rainfall and temperature patterns with a more significant impact observed from maize responses to temperature.

Changes in climatic variables such as rainfall, temperature, windstorm and humidity invariably affect the output of crops negatively. As highlighted by the respondents, the impact may affect the crops at any stage of the production process right from the land preparation to maturity stage of crops but more profound effect is observed at fruit development and maturation stages.

Similarly, majority of farmers indicated that changes in temperature affect crop yield especially during the fruit/seed development stage. Some farmers also acknowledged the impact of changes in rainfall on fruit development stage, germination and maturation stages of crop production.

The study revealed that majority of farmers, (about 92.2%) have observed climate change in the study area and indicated events like unpredictable rainfall pattern, excessively high temperatures and strong winds. More so, to confirm their observations that indeed the climate has changed, they linked CC to specific events like sounds of some animals such as frogs and crickets which for a long time have been aligned to the onset of rains but which have changed completely.

6.1.3 Adaptation strategies

The study discovered that farmers respond to climate change (CC) by adopting various strategies which are informed by their years of farming experience in particular. Based on years of farming experience, farmers adopt measures such as mixed cropping, mulching, crop diversification and using of sticks to support crops as in the case of plantain and maize. All these measures and a few others like irrigation and use of agrochemicals (not popular among the farmers) were identified to be the only means of adapting to CC and its impacts on crop production.

6.2 CONCLUSION

The study applied the "DPSIR model" grounded in the "Neo-Malthusians theory of high population growth and environmental degradation", to the objectives. In the first place, the study sought to examine farming practices that contribute to climate change (that is anthropogenic factors to CC) The results identified some perceived farming practices that contribute to climate change as slash and burn, bush burning, deforestation and fertilizer application. The driving-force component of the DPSIR framework holds that in quest for man to meet his insatiable needs, due to drivers such as large family size (high population), he intervenes with the environment by way of agriculture to get sufficient food to feed the family and thereby exert pressure on the natural environment.

The OLS model used to determine the actual impacts of CC on crops showed that negative impacts which implies that the pressures due to driving-forces result in change of state of the environment (e.g. climate change) and in the long run impacts agricultural activities negatively. Eventually, this calls for national and global concern and response to deal with the problem of food scarcity due to climate change impacts. This is clearly evidenced in the various individuals and institutional adaptation strategies.

The results justify the null hypothesis that: H_0: the perceptions of farmers on indicators of climate change and determinants of adaptation do not differ significantly ($p > 0.05$). We therefore fail to reject H_0. However we accept the H_1 of hypothesis that: H_1: there is statistically significant impact of changes in rainfall and temperature pattern on food availability.

6.3 RECOMMENDATIONS

Climate change is a natural phenomenon and therefore cannot be prevented by man no matter how devastating its impacts on earth systems might be. However it is prudent to heed to various recommendations from research outcomes in order to cope with the situation as it persists. Based on the data collected and the results obtained after the analyses, the following recommendations are made.

First, to address national food insecurity, there is a need for GMA and MoFA through their arms of extension services to translate the available knowledge and experiences from farmers on climate change mitigation into action through the design and implementation of evidence based interventions.

Again, capacity building and awareness creation should be enhanced GMA and MoFA through the media to ensure that communication about climate change and food security is meaningful. The irony from the findings is that farmers are aware that some farming practices they adopt result in some of these micro and macro scale changes in climatic variables like rainfall, temperature and windstorm which they also perceived as plaguing their livelihood activities, yet they remain helpless and stick to these same practices. This means that education on diversification of farming methods has not been enough if there is any at all in the area. Awareness creation therefore allows people to make informed and responsible decisions towards sustainable farming practices which will lead to food security and also environmental sustainability.

Furthermore, one key factor that informed better adaptation measures which was highlighted most by farmers in all the sampled study communities was years of farming experience. It is therefore recommended that since farmers" years of farming experience was pointed out as a major determinant of effective adaptation, appropriate platforms should be made available to such experienced farmers by the extension service providers from MoFA and GMA, so that they can translate their knowledge on climate change impact on crop production to the young and upcoming farmers. This can be done through symposia, holding discussions regularly on the radio and deploying experienced farmers to the various farming communities to help share their experiences.

Additionally, irrigation was least adopted by farmers in the study area. Irrigation was said to be too expensive and water for irrigation was also said to be nonexistent and the available few rivers and streams have also been rendered worthless by illegal mining activities in the area. It is therefore recommended that the government and other stake holders like NGO‟s should help provide irrigational facilities to farmers to be able to cultivate in times of dry spells and delayed rains. Also the government and local authorities (traditional and modern) should enact and enforce by-laws that would prohibit illegal mining activities near water bodies in the farming communities.

It is also recommended that farmers should be supported by government by means of providing them with subsidized seeds with shorter gestation periods so that CC impacts on crops such as maize which are seasonal in nature would be reduced.

Finally adaptation measures is recommended to be made stage specific and crop specific by farmers in the cultivation process since certain stages or points in the production process were discovered to be more sensitive to CC impacts. For instance it is recommended that during fruit development and maturity stages in the production of crops like maize and plantain, adaptation measures such as supporting the crop with strong sticks and providing wind breaks against heavy rains and windstorms would be more appropriate to adopt.

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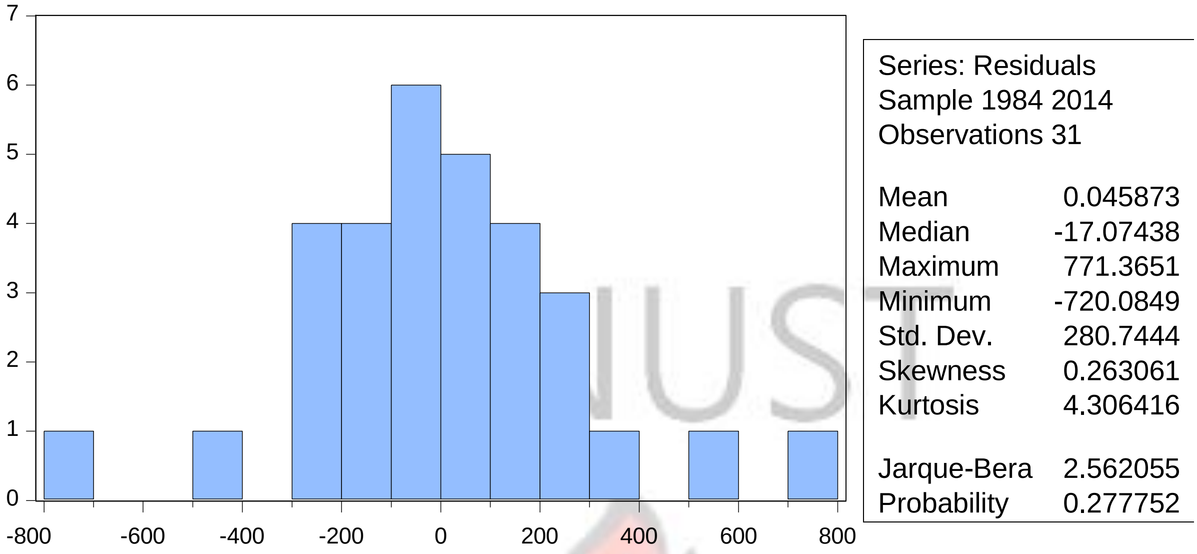
APPENDICES

(A) EVIEWS RESULTS FOR MAIZE

Dependent Variable: OUTPUT_M				
Method: Least Squares				
Date: 03/02/15 Time: 01:37				
Sample: 1984 2014				
Included observations: 31				
OUTPUT_M = C(1)*LA_HA_M + C(2)*RAINFALL + C(3)*TEMP				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.970040	0.143479	13.73048	0.0000
C(2)	-0.636676	0.382743	-1.663456	0.1074
C(3)	-72.96117	30.24064	-2.412686	0.0226
R-squared	0.880402	Mean dependent var		7064.428
Adjusted R-squared	0.871860	S.D. dependent var		811.8015
S.E. of regression	290.5981	Akaike info criterion		14.27353
Sum squared resid	2364523.	Schwarz criterion		14.41230
Log likelihood	-218.2396	Hannan-Quinn criter.		14.31876
Durbin-Watson stat	1.776569			

(B) NORMALITY TEST FOR MAIZE OUTPUT



Series: Residuals
Sample 1984 2014
Observations 31
Mean 0.045873
Median -17.07438
Maximum 771.3651
Minimum -720.0849
Std. Dev. 280.7444
Skewness 0.263061
Kurtosis 4.306416
Jarque-Bera 2.562055
Probability 0.277752
0
1
2
3
4
5
6
7
-800
-600
-400
-200
0
200
400
600
800

(C) GODFREY SERIAL CORRELATION LM TEST FOR MAIZE OUTPUT:

F-statistic	0.272158	Prob. F(1,27)	0.6061
Obs*R-squared	0.309359	Prob. Chi-Square(1)	0.5781

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/02/15 Time: 01:38
Sample: 1984 2014
Included observations: 31
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.008208	0.146230	0.056134	0.9556
C(2)	0.086541	0.421806	0.205168	0.8390
C(3)	-5.912341	32.67019	-0.180970	0.8577
RESID(-1)	0.110177	0.211194	0.521688	0.6061

R-squared	0.009979	Mean dependent var	0.045873
Adjusted R-squared	-0.100023	S.D. dependent var	280.7444
S.E. of regression	294.4503	Akaike info criterion	14.32801
Sum squared resid	2340927.	Schwarz criterion	14.51304
Log likelihood	-218.0842	Hannan-Quinn criter.	14.38833
Durbin-Watson stat	1.925600		

(D) HETEROSKEDASTICITY TEST FOR MAIZE: BREUSCH-PAGAN-GODFREY

F-statistic	0.209885	Prob. F(3,27)	0.8887
Obs*R-squared	0.706463	Prob. Chi-Square(3)	0.8717
Scaled explained SS	0.952868	Prob. Chi-Square(3)	0.8127

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/02/15 Time: 01:39
Sample: 1984 2014
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1766879.	2717841.	0.650104	0.5211
LA_HA_M	-8.196516	79.05228	-0.103685	0.9182
RAINFALL	-66.21913	195.7606	-0.338266	0.7378

BREUSCH-

TEMP	-56152.87	103479.6	-0.542647	0.5918

R-squared	0.022789	Mean dependent var	76274.94
Adjusted R-squared	-0.085790	S.D. dependent var	140991.3
S.E. of regression	146914.7	Akaike info criterion	26.75301
Sum squared resid	5.83E+11	Schwarz criterion	26.93804
Log likelihood	-410.6716	Hannan-Quinn criter.	26.81332
F-statistic	0.209885	Durbin-Watson stat	2.242584
Prob(F-statistic)	0.888663		

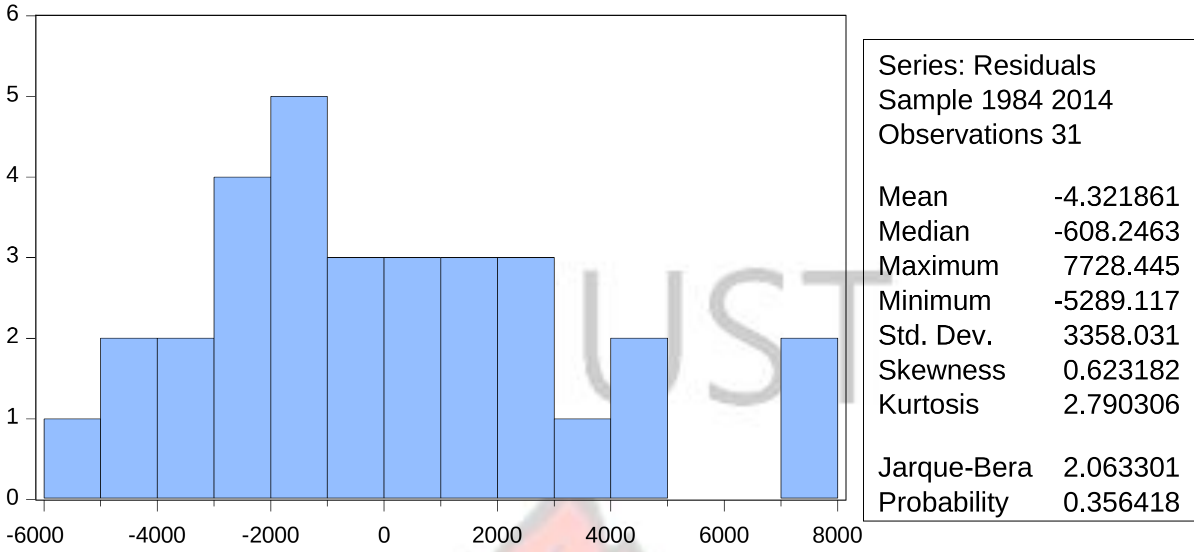
(E) EVIEWS RESULTS FOR CASSAVA

Dependent Variable: OUTPUT_C
Method: Least Squares
Date: 03/02/15 Time: 01:33
Sample: 1984 2014
Included observations: 31
OUTPUT_C = C(1)*LA_HA_C + C(2)*RAINFALL + C(3)*TEMP

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	11.14157	1.521180	7.324298	0.0000
C(2)	-6.547095	4.522217	-1.447762	0.1588
C(3)	-8.494679	470.1725	-0.018067	0.9857

R-squared	0.657164	Mean dependent var	74135.99
Adjusted R-squared	0.632676	S.D. dependent var	5735.115
S.E. of regression	3475.895	Akaike info criterion	19.23686
Sum squared resid	3.38E+08	Schwarz criterion	19.37563
Log likelihood	-295.1713	Hannan-Quinn criter.	19.28209
Durbin-Watson stat	1.910225		

(F) NORMALITY TEST FOR CASSAVA OUTPUT



(G) GODFREY SERIAL CORRELATION LM TEST CASSAVA OUTPUT

F-statistic	0.022015	Prob. F(1,27)	0.8831
Obs*R-squared	0.025203	Prob. Chi-Square(1)	0.8739

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/02/15 Time: 01:35
Sample: 1984 2014 Included observations: 31
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.043435	1.575891	0.027562	0.9782
C(2)	-0.050228	4.615755	-0.010882	0.9914
C(3)	-9.080715	482.5023	-0.018820	0.9851
RESID(-1)	0.029655	0.199868	0.148374	0.8831

R-squared	0.000813	Mean dependent var	-4.321861
Adjusted R-squared	-0.110208	S.D. dependent var	3358.031
S.E. of regression	3538.236	Akaike info criterion	19.30056
Sum squared resid	3.38E+08	Schwarz criterion	19.48559
Log likelihood	-295.1587	Hannan-Quinn criter.	19.36087
Durbin-Watson stat	1.953628		

(H) HETEROSKEDASTICITY TEST FOR CASSAVA OUTPUT: BREUSCH-PAGAN-GODFREY

BREUSCH-

F-statistic	1.417171	Prob. F(3,27)	0.2594
Obs*R-squared	4.217297	Prob. Chi-Square(3)	0.2389
Scaled explained SS	3.074202	Prob. Chi-Square(3)	0.3803

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/02/15 Time: 01:36
Sample: 1984 2014
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-45356948	2.58E+08	-0.176133	0.8615
LA_HA_C	8482.174	6639.119	1.277605	0.2123
RAINFALL	-30447.40	18961.70	-1.605732	0.1200
TEMP	1286923.	8921103.	0.144256	0.8864

R-squared	0.136042	Mean dependent var	10912638
Adjusted R-squared	0.040046	S.D. dependent var	14829200
S.E. of regression	14529237	Akaike info criterion	35.94114
Sum squared resid	5.70E+15	Schwarz criterion	36.12617
Log likelihood	-553.0876	Hannan-Quinn criter.	36.00145
F-statistic	1.417171	Durbin-Watson stat	2.128182
Prob(F-statistic)	0.259382		

(I) EVIEWS RESULTS FOR PLANTAIN

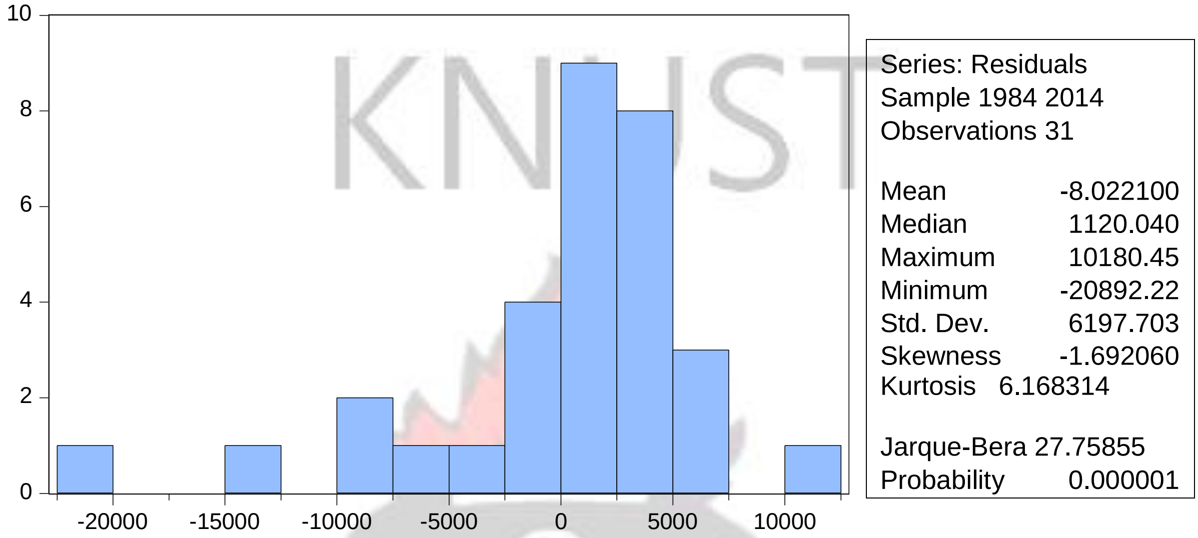
Dependent Variable: OUTPUT_P
Method: Least Squares
Date: 03/02/15 Time: 01:42
Sample: 1984 2014
Included observations: 31
OUTPUT_P = C(1)*LA_HA_P + C(2)*RAINFALL + C(3)*TEMP

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	11.68982	1.405252	8.318666	0.0000
C(2)	6.843917	8.353561	0.819281	0.4195
C(3)	-1005.846	677.0046	-1.485730	0.1485

R-squared	0.721722	Mean dependent var	98386.11
Adjusted R-squared	0.701845	S.D. dependent var	11748.75
S.E. of regression	6415.238	Akaike info criterion	20.46251
Sum squared resid	1.15E+09	Schwarz criterion	20.60128
Log likelihood	-314.1688	Hannan-Quinn criter.	20.50774

Durbin-Watson stat	1.889999

(J) NORMALITY TEST FOR PLANTAIN



(K) GODFREY SERIAL CORRELATION LM TEST FOR PLANTAIN:

F-statistic	0.002986	Prob. F(1,27)	0.9568
Obs*R-squared	0.003374	Prob. Chi-Square(1)	0.9537

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/02/15 Time: 01:43
Sample: 1984 2014
Included observations: 31
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.024177	1.497800	-0.016142	0.9872
C(2)	-0.065088	8.589370	-0.007578	0.9940
C(3)	12.03489	723.7160	0.016629	0.9869
RESID(-1)	0.011088	0.202910	0.054644	0.9568

R-squared	0.000109	Mean dependent var	-8.022100
Adjusted R-squared	-0.110990	S.D. dependent var	6197.703
S.E. of regression	6532.597	Akaike info criterion	20.52691
Sum squared resid	1.15E+09	Schwarz criterion	20.71194
Log likelihood	-314.1671	Hannan-Quinn criter.	20.58723

BREUSCH-

Durbin-Watson stat	1.916612

(L) **HETEROSKEDASTICITY TEST FOR PLANTAIN: BREUSCH-PAGAN-GODFREY**

F-statistic	0.527610	Prob. F(3,27)		0.6671
Obs*R-squared	1.716686	Prob. Chi-Square(3)		0.6332
Scaled explained SS	3.625343	Prob. Chi-Square(3)		0.3049
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Date: 03/02/15 Time: 01:44				
Sample: 1984 2014				
Included observations: 31				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.62E+08	1.50E+09	0.108187	0.9146
LA_HA_P	-13700.60	19363.42	-0.707550	0.4853
RAINFALL	-122384.8	115029.5	-1.063943	0.2968
TEMP	6660687.	55096151	0.120892	0.9047
R-squared	0.055377	Mean dependent var		37172507
Adjusted R-squared	-0.049581	S.D. dependent var		85978507
S.E. of regression	88084180	Akaike info criterion		39.54540
Sum squared resid	2.09E+17	Schwarz criterion		39.73043
Log likelihood	-608.9537	Hannan-Quinn criter.		39.60571
F-statistic	0.527610	Durbin-Watson stat		2.224205
Prob(F-statistic)	0.667103			

(M) **MAKESENS TREND TEST SHOWING TREND STATISTICES**

TREND STATISTICS

BAB

				Mann-Kendall trend			Sen's slope estimate									
Time series	First year	Last Year	n	Test S	Test Z	Signific.	Q	Qmin99	Qmax99	Qmin95	Qmax95	B	Bmin99	Bmax99	Bmin95	Bmax95
OM	*1984*	*2014*	*31*		3.16	**	47.848	9.992	87.838	18.845	75.996	6372.41	6762.89	5694.59	6730.08	5990.04
LM	*1984*	*2014*	*31*		3.96	***	24.318	9.634	41.937	11.426	37.906	4722.05	4856.46	4477.76	4838.57	4529.75
Temp	*1984*	*2014*	*31*		3.97	***	0.023	0.012	0.033	0.015	0.031	27.35	27.53	27.17	27.49	27.21
Rain	*1984*	*2014*	*31*		1.63		4.856	-3.507	11.742	-0.872	10.626	1327.98	1446.85	1199.55	1386.27	1214.12
OC	*1984*	*2014*	*31*		0.32		22.700	-259.456	208.627	-161.377	159.019	74584.10	77644.46	70689.69	77546.38	71688.57
LC	*1984*	*2014*	*31*		-1.09		-6.522	-20.544	10.000	-16.261	4.059	7682.61	7932.52	7390.00	7845.13	7485.06
Op	*1984*	*2014*	*31*		0.88		176.923	-325.761	946.406	-210.430	707.956	96198.16	101206.80	84298.93	100540.72	87875.68
LP	*1984*	*2014*	*31*		0.53		2.778	-21.407	66.588	-12.642	52.248	9930.00	10121.61	9335.53	10030.78	9483.02
0	*0*	*0*	*0*													

<u>Appendix (N)</u> Farm implements **Crosstab**

			Farm implements			Total
			Yes	No	No idea	
Gvtsupporttoadapt	Yes	Count	0	4	0	4
		% of Total	0.0%	2.6%	0.0%	2.6%
	No	Count	2	143	1	146
		% of Total	1.3%	92.9%	0.6%	94.8%
	No idea	Count	1	3	0	4
		% of Total	0.6%	1.9%	0.0%	2.6%
Total		Count	3	150	1	154
		% of Total	1.9%	97.4%	0.6%	100.0%
Pearson Chi-Square			0.02			

<u>Appendix (O)</u> Extension service
Crosstab

			Extension service			Total
			Yes	No	No idea	
Gvtsupporttoadapt	Yes	Count	1	3	0	4
		% of Total	0.6%	1.9%	0.0%	2.6%
	No	Count	39	106	1	146
		% of Total	25.3%	68.8%	0.6%	94.8%
	No idea	Count	3	1	0	4
		% of Total	1.9%	0.6%	0.0%	2.6%
Total		Count	43	110	1	154
		% of Total	27.9%	71.4%	0.6%	100.0%

<u>Appendix (P)</u> **vtsupporttoadapt * Finance Crosstabulation**

			Finance			Total
			Yes	No	No idea	
Gvtsupporttoadapt	Yes	Count	0	4	0	4
		% of Total	0.0%	2.6%	0.0%	2.6%
	No	Count	1	144	1	146
		% of Total	0.6%	93.5%	0.6%	94.8%
	No idea	Count	0	4	0	4
		% of Total	0.0%	2.6%	0.0%	2.6%
Total		Count	1	152	1	154
		% of Total	0.6%	98.7%	0.6%	100.0%

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF GEOGRAPHY AND RURAL DEVELOPMENT

SCHOOL OF GRADUATE STUDIES

<u>Appendix(Q) Questionnaire</u>

THESIS TOPIC:

CLIMATE CHANGE AND FOOD CROP SECURITY IN GHANA - BIBIANI AHWIASO BEKWAI DISTRICT IN PERSPECTIVE

Name of Community………………………….

Dear respondents

(I promise that information obtained from any stakeholder would be treated with utmost confidentiality)

<u>QUESTIONNAIRE</u>

This questionnaire is purely designed to solicit views of respondents (farmers) concerning their perceptions on climate change impacts on food crop production in the district and the way forward.

The questions are categorized under the following themes

1. Farmer‟s perception on local indicators of climate change.
2. Adaptation and coping strategies by farmers.
3. Farmer‟s perception on the effects and or impacts of climate change on their output levels.

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF FARMERS

No.	Questions	Response (Please tick appropriately the correct answer)
1	Gender	1. Male [ ] 2. Female [ ]
2	Age	1. 31-40years [ ] 2. 41-50years [ ] 3. 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 food crop cultivation	1. 21-30 years [ ] 2. 31- 40years [ ] 3. 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 Total monthly expenditure GH¢…………………………………… Total annual expenditure GH¢…………………………………… All expenses on the listed items plus all other expenses should add up to the total monthly expenditure.	 **Items** Food and water Labour Transportation Farm tools (Cutlass, hoe, watering cann etc. Seeds and Seedlings Agro-chemicals (fertilizer, 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 [ ]
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: PERCEPTION ON CLIMATE CHANGE IN THE DISTRICT

15 Have you observed any 3. Yes [ ] changes of the climate
over 4. No [ ]
the past decades? 5. No idea [ ]

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

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

18 What has been the rainfall Intensity High [ ]
Low [ ] pattern in this community for Quantity
High [ ] Low [ ]
the past 30 years in terms of Timing Right time [ ] Delay [ ]
intensity, quantity and timing?

19 What other indicators do you Specify ……………………
consider as representing climate change locally in this
area

20 Have you experienced any 1. Yes [ ] drought condition
over the 2. No [ ]
last 30 years? 3. No idea[ ]

21 If yes, how do you describe Severity Highly [Moderately
[Low [ ] the drought condition in this]]
community in terms of Longevity Very long [ ] Moderate [ ] Short [
] severity and longevity?

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

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

24 How do you foresee future 1. More warming [ ] changes
of climate in this 2. Low warming [ ] area? 3. No warming
[ ]

25 Do you receive information 1. Yes [ ] or data from the
weather 2. No [ ] station

26 Have you e
observed any x

	treme climatic event in your locality over the past decades?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
27	If yes what kind of climatic event have you observed during these periods	1. Flood [ ] 2. Drought [ ] 3. Strong winds [ ]
28	In your opinion, does the extreme climatic event have any effect on food crop production?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
29	If yes, at what point of production does it affect	1. Land preparation [ ] 2. Germination stage [ ] 3. Tuber, Seed or Fruit development [ ] 4. Maturity stage [ ]
31	To what extent do drought affect crop production	Increase / Decrease / No effect

SECTION C. EFFECT OF RAINFALL AND TEMPERATURE CHANGES ON FOOD CROP AVAILABILITY (OUTPUT)

32	Is there any possible relationship between rainfall and crop output	1. Yes [ ] 2. No [ ]
33	If yes, which type of relationship exist	1. Positive [ ] 2. Negative [ ]
34	Do changes in rainfall pattern affect your output?	1. Yes [ ] 2. No [ ]
35	If yes, what is the degree of effect?	Increase / Decrease / No effect
36	Do changes in temperature affect your output?	1. Yes [ ] 2. No [ ]
37	To what extent does it affect your output?	Increase / Decrease / No effect
38	Do you only rely on rainfall for the cultivation?	1. Yes [ ] 2. No [ ]
39	If no, identify some of the methods you adopt	

SECTION D. PERCEPTIONS ON THE EFFECTS OF CLIMATE CHANGE ON FOOD CROP PRODUCTION

40	How do you perceive climate change 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……………………………………
41	What is the level of your knowledge on climate change?	1. Very good [ ] 2. Good [ ] 3. Very poor [ ] 4. Poor [ ] 5. Don"t know [ ]
42	How do you perceive the effect of climate change 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 [ ]
43	Do you think the climate is changing at a rate that is significantly affecting food crop availability?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
44	Do you think the climate is changing at a rate that is significantly affecting food crop accessibility?	1. Yes [ ] 2. No [ ] 3. No idea [ ]
45	If yes, how?	
46	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 [ ]
47	What is the trend of the quantity of crop yield	1. Increase [ ] 2. Decrease [ ]
48	If your yield decreases, what might possibly be the cause for that?	
49	What human factors are responsible for climate change 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. Fertilizer application Yes [ ] No [ ]

SECTION G. ADAPTATION TO CLIMATE CHANGE IMPACT

50	Which of the following adaptation options do you adopt in the event of crop failure due to the changing climate?	1. Crop diversification Yes [ ] No [ ] 2. Diversification to non-farm activities Yes [ ] No [ ] 3. Use of agrochemicals Yes [ ] No [ ] 4. Mixed cropping Yes [ ] No [ ] 5. Changing crop varieties Yes [ ] No [ ] 6. Irrigation farming Yes [ ] No [ ] 7. Changes in farm location Yes [ ] No [ ] 8. Mulching Yes [ ] No [ ] 9. Do nothing Yes [ ] No [ ]
51	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………………….
52	What is the degree of effectiveness of the various adaptation practices you employ?	1. Very effective [ ] 2. Moderately effective [ ] 3. Not effective [ ]
53	Do the following affect your ability to adapt to the changes in climate?	(see table below)
54	Which of the following do you practice?	1. Irrigation farming [ ] 2. Non irrigation farming [ ]
55	Why are you not employing irrigation	1. It is costly [ ] 2. It is tedious [ ] 3. Just don"t like it [ ]
56	Do you receive support (e.g. extension services, finance etc.) from the government	1. Yes [ ] 2. No [ ] 3. No idea [ ]
57	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 [ ]

Question 53:

	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		

58	If yes, what kind of training do you receive?	
59	What kind of government support do you receive to help you adapt to the varying	1. Extension services [ ] 2. Finance [ ] 3. Agro-chemicals [ ]
	climate to boost your production	4. Farming tools and equipment [ ] Other, specify……………
60	What is the impact of these support systems on your production?	1. Increase yield [ ] 2. Decrease yield [ ] 3. Constant yield [ ]
61	Apart from the climate, what other challenges affect food crop production in the district	

THANK YOU FOR YOUR TIME AND ENERGY