CLIMATE VARIABILITY AND FOOD CROP PRODUCTION IN THE BAWKU MUNICIPALITY

by

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DECLARATION

I hereby declare that except for references cited, which have been duly acknowledged, this thesis is the result of my own research. It has never been presented anywhere either in part or whole for the award of any degree.

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DEDICATION

This work is dedicated to my family especially to my late grandparents Hajia Fatima Ayumah and Col (Rtd) Alhaji Seidu Ayumah.

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ABSTRACT

Climate variability threatens the sustainability of food crop production. It is therefore important to understand the interaction between climate variability and food crop production. This study examined the effect of climate variability on food crop production in the Bawku Municipality. Five farming communities were selected in the Bawku Municipality as the study sites. Quantitative and qualitative data were sourced from both primary and secondary sources. Questionnaires, focus group discussions and oral narratives were used as data collection tools to assess the situation. Quantitative data were analysed with SPSS and E-views and the results presented in the form of charts and tables whiles qualitative data were analysed thematically to support the quantitative data. The results indicate a significant variation in annual rainfall for the 15 year period (1999 to 2013) but mean temperature variation in the Municipality was relatively stable. The results of the regression model revealed that rainfall significantly explains variation in maize production while temperature was not significant in explaining the variation of rice, maize and millet production. The study revealed that farmers are particularly vulnerable to climate variability owing to their low capital assets, exposure to frequent drought, floods and wind storms. As copping strategies, some farmers have resorted to migration, trading, crop and livelihood diversification to enhance their living conditions. These strategies are however, not sufficient to sustain food crop production in the Municipality in the long term. To sustain and enhance the livelihoods of food crop farmers, the study recommends that urgent financial, education, capacity building, infrastructure and institutional support are needed to improve food crop production and make farmers' livelihoods resilient to climate variability.

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LIST OF ABBREVIATIONS

AMO	Atlantic Multi-decadal Oscillation
AO	Arctic Oscillation
CA	Capability Approach
CCFS	Climate Change and Food Security
DFID	Department for International Development
ENSO	El Niño-Southern Oscillation
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GMA	Ghana Meteorological Agency
IPCC	Intergovernmental Panel on Climate Change
MoFA	Ministry of Food and Agriculture
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
PDO	Pacific Decadal Oscillation
SARI	Savanna Agricultural Research Institute
UNFCCC	United Nation Framework Convention on Climate Change
UNDP	United Nations Development Programme
WMO	World Meteorological Organization

CHAPTER ONE

BACKGROUND TO THE STUDY

1.0 Introduction

Climate is a renewable resource which varies on all time scales, from year to year, as well as from one decade, century or millennium to the next (Ghil, 2002). The variation in the climate system on all temporal and spatial scales is referred to as climate variability (Intergovernmental Panel on Climate Change-IPCC, 2007). The complex nature of this variability is a major hindrance to the consistent detection of global alterations (Ghil, 2002). Under global warming, it is expected that climate variability will increase and climate extremes will become more intense and frequent in the future (Department for International Development-DFID, 2004; cited in Scott, 2008). The process of global warming shows no signs of diminution and is expected to bring about long term variations in weather conditions (Food and Agricultural Organisation-FAO, 2008). This warming of the world has been linked to higher concentration of greenhouse gases in the atmosphere. The main causes are the burning of fossil fuels (coal, oil and gas) to meet rising energy demand, and the spread of intensive agriculture to meet growing food demand (FAO, 2008). The consequences of which can be manifested in the higher frequency of extremes such as floods, drought and cyclones (Kandji *et al.,* 2006).

Scientific evidence suggests that climatic variations have long term negative impacts on agricultural productivity globally (Nellemann *et al.,* 2009). For instance, in the tropics and subtropics, crop yields are likely to fall by 10% to 20% because of increased adverse effects climate variability (Thornton *et al.,* 2007). Hence, it is imperative that climate variability and climate change are well understood so as to formulate more sustainable policies and strategies to promote food security (World Meteorological Organisation, 2001; cited in Scott, 2008). Particularly in Africa, climate variability and climate change issues need urgent attention, because a third of Africa’s people already live in drought-prone regions and climate variability and change could put the lives and livelihoods of an additional 75 to 250 million people at risk by the end of the next decade (Fleshman, 2007). Recent studies have shown that for each 1°C rise in average temperature, farmers’ income in Africa will drop by nearly 10% (FAO, 2008). This shows that heightened year-to-year variation of climate and changing local factors can markedly affect income from agricultural production, costs to consumers, and food scarcity (Molua, 2002). This could intensify economic hardship on the continent. Livelihoods for this reason will be put in jeopardy. The myriad impacts according to the IPCC (2007) would be experienced differently across the continent due to other socio-economic challenges. Africa is therefore considered to be the most vulnerable region to climate variability because it is exposed climate risks, reliance on fed agricultural and also has low adaptive capacity because of high rate of poverty (IPCC, 2007).

Ghana has revealed distinctive inter-annual and inter-decadal variability in climatic variables like precipitation and temperature. The total duration of the rainy season is also revealed to have shortened, while dry season and rainy season temperatures have increased by about 1°C and 2°C respectively (Kunstmann and Jung, 2005; cited in Amikuzuno and Donkoh, 2012). Christensen *et al.* (2007) have observed that inter-annual variability in rainfall is expected to increase, with a rise in the intensity of high rainfall events but an overall decrease in the number of rainy days. A comparison of the mean annual rainfall differences from 1951-1970 and 1981-2000 at meteorological stations across Ghana also indicated little rainfall over time. These variations are greatest in the northern sector and are projected to increase some more (Owusu and Waylen, 2009). This situation will significantly constrain the sustainability of rain-fed farming systems with severe impacts on crop yields (Fosu-Mensah, 2012 and Acquah, 2011). Hence, climate variability is considered as one of the banes of food crop production especially in Northern Ghana. The consequences will not only be limited to the agricultural sector but will be felt in other sectors of the economy. Though the agricultural sector has lost its position as the largest contributor to Gross Domestic Product (GDP) to the service sector, it still employs more than half of Ghana's population (Acquah, 2011). Any uncertainties due to climate variability and extreme climatic events will therefore cause great devastation in the economy of the country. The inadequate rainfall in 1982-1983, is a testament of how drought destroyed most crops and negatively affected more than 12 million people in the country (Dietz *et al.*, 2004).

Extensive research on the impacts of climate variability/change on agriculture in Ghana revealed that episodes of late onset of rains for planting, variability in the pattern and levels of rainfall, and intermittent droughts and floods are fundamental problems for farmers in northern Ghana (Nyantakyi-Frimpong, 2013; Amikuzuno and Donkoh, 2012; Acquah, 2011). This has become a threat to the livelihoods of food crop farmers in this particular zone (Amikuzuno and Donkoh, 2012). For instance, in 2007, the Northern, Upper East and Upper West Regions were wrecked by marauding flood waters affecting three hundred and seventeen thousand (317,000) people with the Central Gonja District being described as an environmental calamity; because, about twenty six thousand, eight hundred and twenty two (26,822) acres of farm lands were destroyed (Oppong-Ansah, 2011). Crop production data from the three Northern regions of Ghana show that, the production of major staple crops (maize, millet and sorghum) declined substantially during the 2010/2011 growing season compared with the previous year, mainly because of poor rainfall during the critical growing stages (Stanturff *et al.*, 2011).

In view of these fluctuations in the rainfall pattern and corresponding negative changes in food availability, farmers in Northern Ghana have developed intricate strategies to adapt to these fluctuations (Nyantakyi-Frimpong, 2013). It is therefore apparent that if the changing climate continues without appropriate strategies for climate adaptation, the magnitude of economic losses will be higher with greater effect on the poor. The objective of this study is therefore to analyse the effects of climate variability on food crop production among rain-fed crop farmers in northern Ghana.

1.1 Statement of the Problem

Food crop production is a major economic activity in the Bawku Municipality (Acquah, 2011). However, the unfavourable climatic conditions in the area adversely affect crop production (Acquah, 2011).

Declining rainfall in the Municipality reduces the length of the growing season and also delays the onset of the planting season with consequent adverse effect on food crop production (Acquah, 2011). Furthermore, climate variability in recent years frequently causes heavy rains and flooding or intense droughts which devastate farmlands and plunge farmers into economic hardships in the Bawku Municipality (Acquah, 2011).

Lack of investment in agricultural infrastructure in the Bawku Municipality has also resulted in limited use of irrigation facilities during the long dry season posing additional threat to food crop farmers who then rely largely on rain-fed agriculture for their livelihoods. Thus, food crop farmers remain more vulnerable to the variability of climate. More so, the incidence of crop failures force farmers to depend on low-input and low-risk technologies, leaving them unable to derive high yields during favourable seasons (Acquah, 2011).

In the long dry season most farmers as well as farm workers engage in nonfarm activities for survival whiles others migrate to Southern Ghana for menial jobs. The adverse effects inflicted by unfavourable climatic conditions such as drought clearly illustrate the vulnerability of food crop production and farmers in the study area. The Vulnerability of food crop farmers in the Municipality is expected to increase due to predicted frequent climate variability and extreme climatic events such as drought (Amikuzuno and Donkoh, 2012). Strategies must be put in place to ensure more adaptive capacity to confront current and future climate variability and climate extremes. The issue of climate variability and food crop production in Ghana has been extensively investigated; however, little work has been carried out in the Sudan Savanna Climatic Zone of the country. The challenge is therefore to investigate the effects of climate variability on food crop production in the Bawku Municipality in the Sudan Savanna Zone where information is required by stakeholders to devise effective adaptation strategies for farmers in the Municipality.

1.2 Purpose of the Study

Generally, the study seeks to explore the effects of climate variability on food crop production in the Bawku Municipality**.**

1.3 Objectives of the study

Specifically, the study aims to achieve the following objectives:

1. To analyse the influence of observed climatic trends on food crop production in the study area.
2. To assess the vulnerability of food crop farmers in the Bawku Municipality to climate variability.
3. To examine the adaptation strategies employed by food crop farmers in the area of study in response to climate variability.

1.4 Research Question

1. What are the effects of the observed climatic trends on food crop production in the Bawku Municipality?
2. How vulnerable are food crop farmers in the Bawku Municipality to climate variability?

3. What are the adaptation strategies employed by food crop farmers in the Bawku Municipality in response to climate variability?

1.5 Hypotheses

1. $H_{0:}$ Temperature exerts no statistically significant effects on staple foods production in the Bawku Municipality

   $H_{1:}$ Temperature exerts positive effects that are statistically significant on staple foods production in the Bawku Municipality.

2. $H_{0:}$ Rainfall exerts no statistically significant effects on staple foods production in the Bawku Municipality.

   $H_{1:}$ Rainfall exerts positive effects that are statistically significant on staple foods production in the Bawku Municipality.

1.6 Justification/Relevance for the Study

The study is one of a series in an attempt to provide a more in-depth empirical analysis of the effects of climate variability on food crop production with focus on the Bawku Municipality. The study is thus, aimed at revealing how climate variability affects food crop production and to identify the appropriate adaptation measures needed to ameliorate the existing problems and prevent negative effects in the future.

The findings of the study will help policy makers such as the Ministry of Food and Agricultural and the Municipal Asssembly to understand and appreciate the complex interconnections through which climate variability affects food crop production. This would help policy makers to facilitate the integration of the findings and the recommendations of the study into the overall development approaches, agenda and policies of the agricultural sector to create a favourable condition for the sector. It is expected to bring about rapid transformation in the agricultural sector since it seeks to delve into one of the major issues that militate against crop production in the study area.

The findings will also serve as a document that will provide background information on the effects and relationship between climate variability and food crop production. It is expected that information obtained from this study will further provide a condition for policy formulation for local multiple adaptation programmes through education aimed at building the adaptive capacity of farmers and stakeholders in increasing crop yields. Again this study will help identify the weaknesses of current adaptation strategies of farmers that need to be corrected to bring about the desired results.

Moreover, this study will also serve as a secondary source of data and reference to other researchers who want to research in a similar field. Thus, the information provided here will be available for the relevant ministries and development agencies, research and teaching institutions and the private sector investors.

1.7 Scope of the Study

The research covered five farming communities in the Bawku Municipality. These are *Mognori*, *Kuka*, Gosezi, *Zabugu* and *Gentiga* communities. The selection of these communities was partly based on the intensive farming done by the farmers during the rainy and the dry seasons and partly by the high production of staple foods in these communities compared to other communities in the Municipality. It was a survey of only a percentage of the population in the five communities which was generalized for the entire population of the study area. Due to the dynamics of the effects of climate variability on food crop production across geographical areas, this study only emphasized on households of the five farming communities in the Bawku Municipality.

1.8 Limitation of the Study

Due to the high illiteracy rate amongst the populace in the study areas (Ghana Statistical Service, 2014), the researcher had to translate the questions into the local language for respondents to understand. However, respondents were reluctant to provide accurate information on variables such as income level, farm size for fear of being denied any help from government. The problem was mitigated as much as possible; by convincing respondents of the objectives of the research and assured them of the confidentiality of information.

1.9 Organisation of the Study Report

The study is organised into six chapters. It starts with the background of the study which includes the problem statement, objectives of the study, hypotheses, justification, scope as well as limitation of the study. The second chapter reviews literature related to the study. Chapter three explains the research methods and description of the study area. Chapter four presents the results and discussions on the influence of the observed climatic trends on major food crop production in the Bawku Municipality. In the fifth chapter, data collected on farmers' vulnerability and adaptation to climate variability are analysed and presented. Finally, summary, conclusion and recommendations are provided in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter seeks to capture and summarize current research work particularly case studies done on the research topic. The literature review examines studies conducted between 2000 and 2014 from local, regional and international sources. In this regard, documents regarding climate variability, extent of climate variability, effects of climate variability on food crop production, vulnerability and adaptation of food crop farmers have been extensively reviewed. In the process, linkages have been identified which form the basis of the conceptual framework of the study. The chapter is categorised into seven main sections.

Section one takes a broader look at the meaning of climate variability and the causes of climate variability. Section two presents the trends in climate variability at both the global and local level while section three examines the effect of climate variability on food crop production. Vulnerability of farmers to climate variability is presented in section four. The fifth section reviews literature on farmers' adaptation to climate variability whereas sections six and seven present respectively, the theoretical and conceptual frameworks for the study.

2.1 Climate Variability

Climate is typically described by the summary statistics of a set of atmospheric and surface variables, such as temperature, precipitation, soil moisture and sea surface temperature, in a particular region over a particular timescale, usually 30 years while climate variability indicates the variation in the average variables for describing climate over a particular timescale (Ebi *et al*, 2005). It is however, important to note that, there is no agreement on how to define the term "climate variability". Several definitions have been given and these definitions have varied *in tandem* to interpret it in new ways. The term "climate variability" according to Geoff (2004), is used to denote deviation of climate statistics about an established average over a given period of time such as specific month, season or year from a longer period mean of the same variables. In a narrow sense, climate variability is referred to as large-scale variations in atmospheric and ocean circulation (IPCC, 2007). These variations occur as a result of natural (internal) processes within the climate system, as well as in response to additional influences due to human activity or anthropogenic (external factors) factors (Davis, 2011). These internal factors and anthropogenic factors are described in the next section.

2.1.1 Natural causes of climate variability

On an astronomical time scale, the earth's climate system alternates between cold conditions and warm conditions (Shaviv and Veizer, 2003). Evidence suggests that this behaviour is due to cyclical changes in the position of the earth's orbit around the sun and the angle of its rotational axis (Shaviv and Veizer, 2003). This process may be simply linked to the passage of seasons at different times of the year (Davis 2011). It has been observed over the years with reliable experimental proof that, the earth's climate has shown a significant internal (natural) variation and change by the El Nino effect. Such major types of the El Nino causing internal variations of the climate system, as stated by Diaz *and* Cabido (2001); Wanner *et al.* (2001); Hurrell (2003); Delworth and Mann (2000); Mantua and Hare (2001) include the El Niño-Southern Oscillation (ENSO), the Arctic Oscillation/North Atlantic Oscillation (AO/NAO), the Atlantic Multi-decadal Oscillation referred to as AMO, as well as the Pacific Decadal Oscillation known as PDO.

Nonetheless, among the above mentioned causes, Li *et al.* (2011) indicated that ENSO is the strongest natural fluctuation of climate on inter annual timescales, with different global weather consequences based on the periods of higher and lower strength of the ENSO. Aside

ENSO, it is well known that volcanic eruptions have a variety of impacts on the climate system (Church *et al,* 2005). In support of the view above, the Krakatoa and Pinatubo volcanic events in 1883 and 1991 respectively are thought to have lowered global temperatures by 0.3-0.5 degree Celsius (Global dimming) (Oppenheimer, 2003 cited in Grab and Nash 2010). This is evidenced in the report by Ammann *et al.* (2007) who found that, several sharp cooling episodes mark the response to very large volcanic forcing in the pre-industrial era, indicating that there is an association between volcanic eruption and climate variability.

Furthermore, natural variability arises as a result of variations in solar intensity. The influence of solar activity on the earth's climate has been found in many climate parameters from the surface up to the top of the atmosphere (Marsh *et al.*, 2005). Recent studies (Engels and Geel, 2012; Haigh, 2011 and Gray *et al*., 2010) show a strong relationship between solar activity and climate variability. These studies convincingly prove that solar activity or changes in solar intensity affect climate and that has an influence on climate variability. Other empirical studies have revealed that changes in stratospheric water vapour, unusual meteorological pattern, meteorite bombardment, erosion, earthquakes, mountain building, movement of sea beds and ocean trench formation are possible factors of natural variability of the climate system (Met Hadley Office Centre, 2011). From what has been stated by researchers, there is a greater need to understand that climate variability is inevitable since these natural occurrences are bound to happen at any time.

2.1.2 Anthropogenic activities and climate variability.

Research on recent climate variability is increasingly inclined towards the view that anthropogenic greenhouse gas-forcing is becoming the dominant cause of global warming, though not the only process driving the warming trend over the last 60 years (IPCC, 2012).

The comprehensive reports of the IPCC (2012) demonstrate that, it is no longer possible to explicate the sharp temperature rise by natural forcing alone, but it can also be elucidated by anthropogenic activities. The IPCC (2012) observed that since 1950, there is evidence that alteration in climatic extremes are as a consequence of anthropogenic influences. Stott *et al.* (2011) also attributed the significant increase in the observed frequencies of warm seasonal temperatures in many regions to human influence.The evidence provided by the IPCC (2012) and Stott *et al.* (2011) provide a clear perspective on how human activities have a greater impact on the climate system. Most scholars have credited the influence of human activities on the climate system to the advent of the industrial revolution which saw humanity's ability to control the forces of nature and manage their own environment (FAO, 2008). People's ingenuity enabled them to create artificial microclimates, cultivate plants and breed animals with desired characteristics, enhanced soil quality, and controlled the flow of water, develop technologies to further enhance man's activities on earth (FAO, 2008). These human activities have given rise to what is known as "greenhouse gas" (IPCC, 2012). The concentration of greenhouse gases for the past 200 years shows that carbon dioxide, methane and nitrous oxide are the main gases released into the atmosphere (Vermeulen *et al.*, 2012). Among these gases, carbon dioxide (CO_2) is known as the largest contribution which comes from the burning of fossil fuels (Vermeulen *et al.*, 2012).

It is generally agreed that about one quarter of the main greenhouse gases stem from agricultural sources such as land-use change, deforestation and biomass burning (FAO, 2008). Vermeulen *et al.* (2012) explains that, food systems alone contribute about nineteen percent to twenty nine percent (19%–29%) of global anthropogenic greenhouse gas (GHG) emissions. It is also significant to understand that anthropogenic aerosol emissions are another important influence on climate, particularly on the intensity of precipitation event. For example, Li *et al.* (2011) reported in their findings a strong association between atmospheric aerosol loading and extreme precipitation for the United States Great Plains. The authors suggested that although precipitation variability may increase with rising carbon dioxide, the overall decreasing trend is driven by the effects of atmospheric aerosols.

In view of the above assertions, there is strong, robust evidence that human influence, dominated by emissions of greenhouse gases, has altered the climate system. The extent to which the climate system has been altered is reviewed under temperature and rainfall in the next section.

2.2 The Extent of Climate Variability

2.2.1 Temperature

Extensive research has established that there is a statistically significant increase in the global mean state of the climate, and further increases are expected if carbon dioxide and other greenhouse gas emissions are not controlled (IPCC, 2007). Over the past 100 years (1906 – 2005), the earth's average surface temperature has risen by around 0.74°C, with the warming greater over land regions than over the oceans. The rate of warming averaged over the last 50 years is nearly twice the rate for the last 100 years (UNDP, 2007). This implies that the rate of warming could further increase in subsequent years.

Furthermore, an analysis of weather data from more than a thousand (1000) meteorological stations around the world in 2011 revealed that, 2005 and 2010 were the hottest years on record since 1880 (NASA, 2011). According to the analysis the next warmest years were 1998, 2002, 2003, 2006, 2007 and 2009 respectively showing considerable variations for the period of study (NASA, 2011) as shown in Figure 2.1 (Page 14) This finding corroborates that by the Met Office Hadley Centre in 2011.

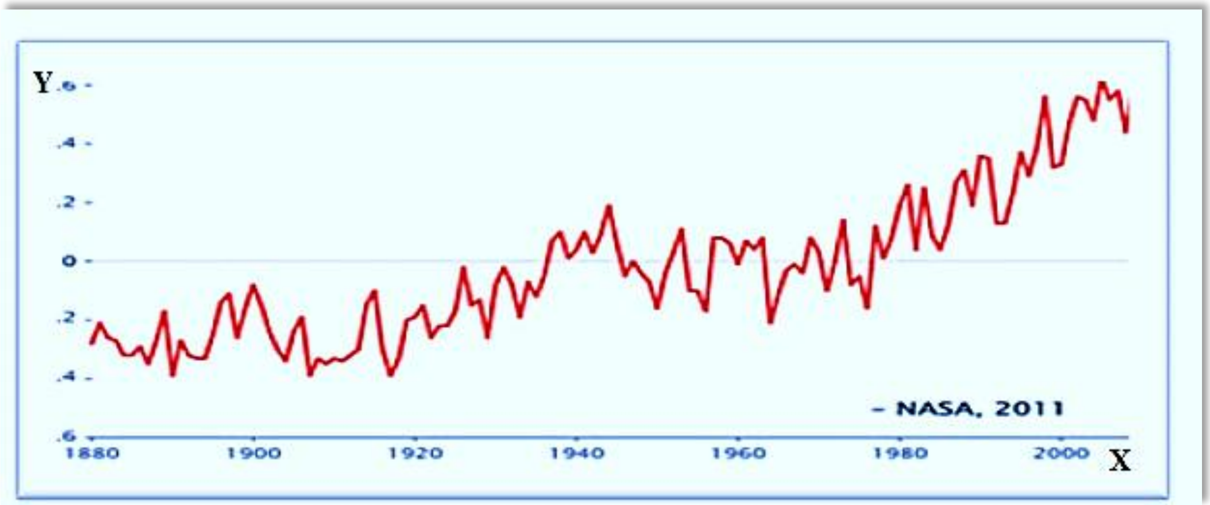


Figure 2.1 NASA research showing warmest years for the period 1880 to 2011.
Source: NASA (2011)

The study by the Met Office Hadley Centre in 2011 revealed that, the average temperature over the first decade of the 21st century (2000- 2009) was significantly warmer than any preceding decade in the instrumental record. Thus, the period 2000–2009 was warmer than the 1990s which, in turn, was also warmer than the 1980s. Despite these variations from year to year which see some years warmer than others, there may be regional variations as compared to the results by NASA and Met Hadley Office Centre. Notwithstanding that, NASA and Met analysis appears to have a comprehensive view of the extent of global temperature variation for the period (IPCC, 2012).

Regionally, observational records also show that during the 20th century, the continent of Africa warmed at a rate of 0.05°C per decade (see Figure 2.2, Page 15) (Hulme *et al.*, 2001 cited in Herrero *et al.*, 2010). This rate of warming was not different from that experienced globally, and the periods of most rapid warming which occurred simultaneously in Africa and the rest of the world (IPCC, 2001 cited in Herrero *et al.*, 2010).

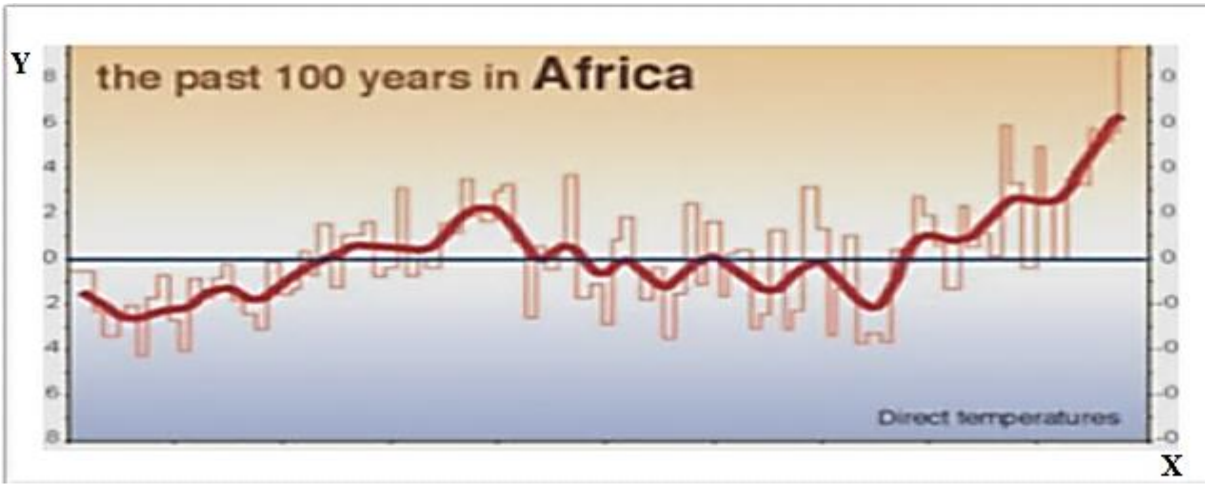


Figure 2.2: Mean temperature anomalies in °C for the last 100 years for Africa
Source: IPCC, (2001).

In support of the temperature anomalies in Africa, Van de Steeg *et al.* (2009) confirmed that 30 years ago, the average temperature of Africa ranged from 8.21°C to 23.21°C; 20 years ago, the average temperature ranged from 9.07°C to 24.7°C; while in the last 10 years alone, the average temperature ranged from 10.50°C to 25.56°C. This clearly depicts an increasing trend in the average temperature of the African region. However, it must be noted that these observations may not explicitly measure changes in daily weather extremes. It explains the extent of temperature fluctuations over the period of study and also helps gain deeper insight into temperature increases over the world.

Correspondingly, in Ghana, since 1960, the mean annual temperature has risen by 1.0°C, with an average rate of 0.21°C per decade (McSweeney *et al.*, n. d; cited in Stanturf, *et al.*, 2011). A research conducted by Dontwi *et al.* (2008) revealed a significant linear increase in mean annual air temperature of about 0.9°C between 1960 and 2001 along the coast of Ghana. According to them, the maximum and minimum temperatures increased by 2.5°C and 2.2°C, respectively, during that time. Comparatively, the rate of increase generally has been more rapid in the Northern parts than Southern regions (Minia, 2008).

In addition, Amikuzuno and Donkoh (2012), in their analysis of climate variability in northern Ghana, revealed that the strong 1997/1998 El Nino effect caused just a slight increase in average minimum and maximum temperatures, but this increase was not significant enough to affect the long term trend in the observed temperatures in the area. As expected, the average minimum and maximum temperatures of the Sudan Guinea Savanna (SGS) zone in the Upper East Region were about 0.9°C and 1.54°C respectively higher than the corresponding values in the Guinea Savanna (GS) zone in the Northern Region. This finding suggests that Northern Ghana has not experienced notable temperature increases over the study period (Stanturf *et al.,* 2011; Amikuzuno and Donkoh, 2012).

In the light of the above, and consistent with what other researchers (Vermeulen *et al*., 2012; IPCC, 2012; Van de Steeg *et al.*, 2009) had found, one can conclude that there has been an increased trend and significant variation in global temperature for the last 100 years. This has therefore informed scientists to conclude that, the world needs to cut emission of greenhouse gases by 50 to 70 percent just to stabilize the level of gases already in the atmosphere (UNDP, 2007); to prevent further warming of the earth.

2.2.2 Rainfall

In relation to rainfall variability, Easterling *et al.* (2000) pinpointed in their study that precipitation intensity, in terms of the number of days with precipitation above 25 mm, shows a statistically significant increase in many areas of the globe. In the same way, using a twenty seven year-long global record of rainfall assembled by the international scientific community from satellite and ground-based instruments; the scientists found some evidence of spatial and temporal variations and trend in precipitation intensity between 1979 and 2005 (NASA, 2011).

According to NASA, (2011), the rainiest year was 2005, followed by 2004, 1998, 2003 and 2002, respectively. From NASA's, (2011) observation, over almost three decades, the total amount of rainfall has seen very little change. However, in the tropics, there has been an increase of 5% for nearly two-thirds of all rainfalls (NASA, 2011). This is contrary to the findings of the IPCC (2007) and Sun *et al.* (2012) which show decreased trends and anomalies of global annual series of precipitation variability.

In addition, Sun *et al.* (2012) on one hand, discovered that the changes in precipitation patterns have led to a redistribution of rainfall such that on average, wet areas and seasons got drier and dry areas and seasons got wetter. Prevailing evidence shows that in semi-arid regions of Africa, the distribution of rainfall has been low and highly variable spatially and inter temporally (Amikuzuno and Donkoh, 2012). Based on the findings above, it is reasonable to state that while some areas are experiencing intensive rainfall, some places are recording a decrease in rainfall amount. Trenberth *et al*. (2007) on the other hand, found no clear significant trend in global average precipitation from 1901-2005, but they confirmed that during that same period global average temperatures had increased. This supports the conclusion of the FAO (2001) that, rainfall in the Sahel from the late 1960s to 1993 was influenced by temperature increases. The findings of Trenberth *et al*. (2007) and the FAO (2001) accentuate the strongly held theory that variability of precipitation will grow with an increase in temperature (Watts, 2012).

At the local level, the situation is not different. Annual rainfall in Ghana is highly variable on inter-annual and inter-decadal timescales, making identification of long-term trends difficult (Amikuzuno and Donkoh, 2012). In the 1960s, rainfall was particularly high and decreased to particularly low levels in the late 1970s and early 1980s. This caused an overall country-wide decreasing trend in the period 1960 to 2006 on an average of 2.3mm per month (2.4

percent)/decade (McSweeney *et al.,* 2010; cited in Stanturf *et al.,* 2011). This was confirmed by a comparison of the mean annual rainfall differences between 1951-1970 and 1981-2000 at meteorological stations across Ghana (Owusu and Waylen, 2009). A study conducted by Amikuzuno and Donkoh (2012) revealed that in northern Ghana, the seasonal variability in the pattern of rainfall over the study period (1976-2010) was quite stark, exhibiting a near-cyclical pattern with the rainfall levels alternating quite regularly between peaks and troughs above the mean rainfall amount of 958.84mm almost triennially. Within the period of the analysis, several episodes of rainfall amount as low as about 600 mm or up to 1800 mm was recorded. Obviously, these increasing compilations of recent research work on temperature and rainfall variations considered as climatic factors of greatest economic and social significance for this study indicate a complete picture of the extent of climate variability.

2.3 Effects of Climate Variability on Food Crop Production

Climate, agriculture and food security are subjects of global concern in recent times. This is obvious from the huge amount of empirical literature (FAO, 2008; Owusu and Waylen, 2009; Fosu-Mensah, 2012; Wheeler and Osbourne, 2013) that is currently available on the subject matter. However, most seem to focus on the industrialized countries where the economic impacts are likely to be less harmful because of better adaptation techniques and technology than the developing nations (FAO, 2008). Though increased production in most food crops is explained by increased area under cultivation as well as improved farming technology, annual fluctuations in production are partly due to climate variability (Peprah, 2014). As a result, the high vulnerability of crops to various manifestations of climate variability has been confirmed in reports of Rowhani *et al*. (2011), Tunde *et al.* (2011), Adamgbe and Ujoh (2013). According to the IPCC (2001), crop production responds to changes in annual mean temperature and precipitation; changes in the distribution of weather; and a combination of changes to the mean and its variability. These sources of climate variability, according to Schlenker and Lobell (2010) and Stanturf *et al.* (2011) affect soil moisture, soil fertility and also increase crop vulnerability to pest infestations, and choking weeds which reduce crop productivity. This phenomenon is examined under the themes that follow.

2.3.1 Effects of temperature variation on crop production

The continuous concentration of greenhouse gases in the atmosphere at rates that are both unprecedented (Siegenthaler *et al.,* 2005) and alarming would result in intense warming (Spahni *et al.,* 2005). Anderson and Bows (2008) and Challinor *et al.* (2004) suggest that this warming will decrease both crop duration and yield, at least up to the optimum temperature for crop development. This will directly affect photosynthesis, respiration and transpiration (loss of water, absorption of water and nutrients) of plants (Fosu-Mensah, 2012), accelerate plant phenology (Tubiello *et al.*, 2000), control the rate of physio-chemical reaction and the rate of evaporation of water from crops and soil surface (Ismaila *et al.,* 2010) and these processes will translate into a 20% yield reduction (Boote and Sinclair, 2006). However, the rate of these processes increases with an increase in temperature for different crops (Fosu-Mensah, 2012). In areas where temperatures are already close to the physiological maxima for crops, such as seasonally arid and tropical regions, higher temperatures may be more immediately detrimental, increasing the heat stress on crops and water loss by evaporation and decrease fertilizer use efficiency (Maracchi *et al*., 2005; Tuck *et al*., 2006 and Olesen *et al*, 2007; cited in Gornall *et al*., 2010).

According to Fosu-Mensah (2012), when temperature exceeds the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield. This has been validated by previous studies. For example, in Australia, extreme air temperatures higher than 38°C led to lower maize grain yields (Ramadoss *et al.,* 2004) while similar temperature for rice led to low productivity (Gornall *et al*., 2010). Other studies by Nguyen (2006), Cooper *et al.* (2009) and Lobel *et al.* (2011; cited in Chijioke *et al.* 2011), have also shown that a 1°C to 2°C rise in mean temperature causes large percentage yield loss in maize.

Considering the yield losses from the findings, the inherent complexity of crop production systems requires integrating many factors to ensure maximum crop yields. One of the most important factors is soil temperature. It has long been recognized that an increase in temperature stimulates the rate of microbial decomposition in the soil which in turn diminishes organic matter content along with nutrient and moisture holding capacity. This indirectly affects total land area suitable for permanent cultivation (Khan *et al.,* 2009 and McCarl, 2006). Crop yield is influenced by the growth, spread and survival of crop pathogens, pests and diseases. These pests and diseases are sustained by temperature. Most analyses show that in a warmer climate, pests may become more active and may expand their geographical range. For instance, recent warming trends in the United States and Canada have led to earlier insect activity in the spring and proliferation of some species, such as the mountain pine beetle (Newman, 2004; cited in Gornall *et al.,* 2010). The evident trend is that temperature variation affects the behaviour of crop pathogen, plants and diseases.

Based on the numerous statements and findings outlined, one would think that temperature variation especially increases in temperature has no positive impact on crop production. Nevertheless, according to the IPCC (2007), under climate variability and change, crop yields will increase in cold areas where low temperature currently limits crop growth whiles moderate warming (increases of 1ºC to 3ºC in mean temperature) is expected to benefit crop and pasture yields in temperate regions. Rosenzweig *et al.* (2007) in their assessment of observed changes and responses in natural and managed systems concluded that 28 ºC local warming in the mid-latitudes could increase wheat production by nearly 10 per cent. They indicated that in some highland regions of Latin America and Africa, for example, growing seasons may extend as temperature increases. However, these increases in mean temperatures are already resulting in longer growing seasons in some parts of the world (IPCC, 2007).

2.3.2 Effects of rainfall variability on food crop production

Generally, rainfall regime is the most important climatic factor influencing crop production. This is because rainfall has the biggest effect in determining the crops that can be grown in different environments, the type of agricultural system to be practised in different parts of the world, the farming system, the sequence and timing of farming operations (Adejuwon, 2005; cited in Ayanlade and Orimoogunje, 2010 and Tunde *et al.,* 2011).

In respect to the above, Tunde *et al.* (2011) and Fosu-Mensah (2012) have identified some important factors guiding rainfall in relation to crop production. According to them, the number of rainy days (the length of the rainy season), time of fall (onset) and total amount of fall, cessation and the type of soil are some of the important factors guiding rainfall in relation to crop production. Therefore, an interruption in the onset, length of the rainy season and cessation will affect soil moisture (soil moisture deficit and enhanced soil moisture), hence, crop development. According to Fosu-Mensah (2012), soil moisture deficit and also the timing of moisture deficits during growing seasons cause crop damage in stages of plant development. As such, water use for a given crop is a function of both the amount of water available to the crop and when that water is available relative to crop demand. On one hand, Rosenzweig *et al.* (2001) affirmed that enhanced soil moisture encourages the spread of nematodes and roundworms that inhabit water films or water-filled pore spaces in soils.

Moreover, increases in rainfall intensity in other regions could lead to higher rates of soil erosion, leaching of soil nutrients and agricultural pollutants, and runoff that carries soil and associated nutrients into surface water bodies leaving the soil impoverished to support plant growth (Kumar *et al.,* 2004; cited in Gornall *et al.,* 2010). If erosion and leaching of soil rates go unchecked, continued soil impoverishment would eventually force farmers to abandon their lands (Khan *et al.,* 2009). From the foregoing, both direct and indirect effects of moisture stress make crops more vulnerable to damage by pests, especially in the early stages of their development. According to Cheke and Tratalos (2007 cited in Gornall *et al.*, 2010), rainfall variability has the tendency to cause pest migration. A typical example is the migration pattern of locusts into Sub-Saharan Africa which Mowa and Lambi (2006) believe is influenced by variability in rainfall patterns. The migration of these locusts into Sub-Sahara Africa poses danger to food security and livelihoods in the region.

Historically, many of the largest declines in crop productivity have been attributed to sudden low precipitation events (Kumar *et al.,* 2004 and Sivakumar *et al.,* 2005 cited in Gornall *et al.,* 2010). An open question is how susceptible food crop production might be to increased rainfall variability? Several studies have been carried out on specific crops in different parts of the world to reveal the situation on the ground. For example, according to Wheeler and Osbourne (2013), globally, between 1960 and 2009, rice yields declined significantly as a result of low rainfall. Consideration of the observed relationship between yield and climate suggests that the significant reduction in the variability of rainfall may have contributed to the reduction in rice yield. Similarly, recent analysis by Asha *et al.* (2012) in India also concluded that the yields of sorghum, maize, pigeon pea, groundnut, wheat and onion have decreased by up to 43.03, 14.09, 28.23, 34.09, 48.68 and 29.56 kilograms per hectare respectively. The decrease in the crops yield, according to sampled farmers is attributed to the reduction of rainfall.

Irrespective of the afore-stated studies, Cabas *et al.* (2010) are of the view that, with prolonged rainfall, some crops are likely to exhibit reduced yields while others will show improved yields. A case in point is a research carried out in Argentina which showed that during the last decades of the twentieth century, increases in the yield of summer crops were caused primarily by increases in precipitation (Magrin *et al.*, 2005). In support of the above findings, Bradford *et al.* (2006) added that in wetter areas, warmer temperatures have less influence on water availability and can increase production by promoting longer growing seasons and faster photosynthetic rates. However, it is important to note that, minor changes in rainfall pattern during stages of crop production threaten crop productivity particularly if the rains fail to arrive during the crucial growing stage of the crops (Mowa and Lambi, 2006). Generally, at aggregated level as well as at the plot level, rainfall variability is a primary cause of inter annual yield variability (Thornton *et al.,* 2014).

2.3.3 Extreme climatic events and food crop production

The definition of what constitutes extreme weather differs for the properties of weather such as temperature, rainfall and wind speed for a region (Porter and Semenov, 2005). Extreme weather events are not new phenomena in agriculture but they are anticipated to increase in their occurrence and the areas subjected to extreme events are likely to expand (Schmidhuber and Tubiello, 2007; cited in Chijioke *et al.,* 2011). However, much uncertainty remain in terms of how changes in frequency and severity of extreme climate events will affect crops (Stanturf *et al.,* 2011). The situation becomes worrying when these extreme events occur sporadically.

According to Rosenzweig *et al.* (2001), under drought stress, most crops’ stomata close which reduce transpiration and, consequently, raise plant temperatures. This affects the flowering, pollination, and grain-filling of most grain crops because most of these grain crops are sensitive to water stress. Similarly, heavy rainfall events leading to flooding can wipe out entire crops over wide areas, and excess water can also lead to other impacts including soil water logging, anaerobicity and reduced plant growth (Falloon and Betts, 2010 cited in Gornall *et al.,* 2010). In response to that, Reynolds and Ortiz, (2010) in their study "Adapting crops to climate change", revealed that waterlogging as a result of intense rainfall is detrimental to root growth which eventually impairs all aspects of plant growth. According to them the effects of waterlogging is becoming severe to the extent that, agricultural machinery may simply not be adapted to wet soil conditions. This will indirectly delay farming operations. The main effects of this will be a massive decrease in crop productivity as well as affect those whose livelihoods depend on food crop production.

Although many studies focus on the negative impacts of some extreme climatic events, other studies have also shown that extreme climatic events as a result of increased climate variability and change can bring benefits to many regions. Of particular importance is the tropical cyclone, which has been established to bring some benefits, especially, to many arid regions in the tropics. For instance, according to Walther and Abtew (2006 cited in Gornall *et al.*,2010), it is estimated that tropical cyclones contribute about 15–20% of South Florida's annual rainfall, which can temporarily end severe regional droughts. Examples of such storms are hurricane Gabrielle in 2001 and tropical storm Fay in 2008, which provided temporary relief from the 2000–2001 and 2006–2009 droughts, respectively. Without such rain the regions would have faced extreme water shortage, wildfires and potential saltwater intrusion into coastal freshwater aquifers (Abtew *et al.,* 2009 cited in Gornall *et al.,* 2010). In a similar occurrence, cyclone Eline, which devastated agriculture in Madagascar in February 2000, later made landfall in Southern Africa and contributed significantly to the rainfall in the semi-desert region of Southern Namibia (Gornall *et al.,* 2010). According to the World Climate Reports (2012), such rainfall has beneficial effects on crop production.

2.4 Vulnerability of Farmers to Climate Variability

The concept of vulnerability appears across a range of disciplines, including finance, security, public health, economic development, natural hazards and, of course, climate change (Janssen *et al.,* 2006). Nelson *et al.* (2010) define vulnerability as the susceptibility of a system to disturbances. This according to Nelson *et al.* (2007) is determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt. Based on the definition, Smit and Wandel (2006) observed that vulnerability depends on the exposure and sensitivity to changes, and on the ability of the system to deal with these changes. According to the authors, the concepts "exposure" and "sensitivity" as determinants of vulnerability are almost inseparable and are reliant on the interaction between the characteristics of the system and the climate stimuli. Exposure relates to the degree of climate stress upon a particular unit of analysis; it may be represented by either long-term changes in climate conditions or changes in climate variability, including the magnitude and frequency of extreme events (O'Brien *et al*., 2004). Sensitivity, in its general sense, is defined by Gallopín (2006) as the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances. However, Gbetibouo and Ringler (2009) identified irrigation rate, land degradation index, crop diversification index, percentage of small scale farmers and rural population index as factors that may influence the sensitivity of a farming region. In general, high levels of exposure, high levels of sensitivity and low levels of coping capacity result in high levels of vulnerability (Ruijs *et al.,* 2010).

O'Brien *et al.* (2004) summarize two interpretations of vulnerability in the climate variability and change literature, as the "starting point and end point approach". Vulnerability as an end point posits that adaptations and adaptive capacity determine vulnerability, whereas viewing it as a starting point holds that vulnerability determines adaptive capacity (O'Brien *et al*., 2004). However, in the socio-economic literature on rural livelihoods, it is widely accepted that farming households face three main sources of vulnerability, namely: shocks (unexpected extreme events, for example, an extreme weather event), seasonal variations (including variations in periodicity and amount of rainfall) and long term trends (such as increases in input prices, or long term changes in mean temperature and rainfall) (Ellis, 2000; cited in Simbarashe, 2013). Hence, farmers are vulnerable in relation to seasonal variation, particularly in timing and amount of rainfall, long-term trends such as increased mean temperature and unexpected shocks from extreme climatic events such as storm, flood, cyclone, wildfire and drought (Challinor *et al.,* 2007).

However, the extent of farmers' vulnerability depends on the geographical location of these farmers. In this regard, it is assumed that households within the same agro ecological zone may be exposed to the same level of climate anomaly (drought in this case) (Eakin and Bojorquez-Tapia, 2008; cited in Antwi-Agyei *et al.,* 2013). According to Jennings and Magrath (2009), farmers' vulnerability to climate variability becomes horrifying when farmers especially smallholder farmers depend solely on climatic variables for the cultivation of their crops without considering modern farming practices such as mechanization. This can further intensify their livelihood insecurity and, in turn, reduce the capacity to prepare for and respond to future disasters (UNFCCC, 2011). This implies that the impacts of climate variability have the potential to hinder agricultural development and progress in eradicating poverty among farmers (Khan *et al.,* 2009).

According to Simbarashe **(**2013), farmers' vulnerability manifests itself in poorer countries and communities due to lack of resources or entitlements and lack of capability to respond or adapt to climate variability. Yet, it is the poor, vulnerable, and marginalized within these countries who have the least capacity or opportunity to prepare for the impacts of a changing climate given their limited resources (Nelson *et al.*, 2010). Compounding this problem is the fact that most farmers do not have access to credit facilities and cannot risk all their resources into food production. This implies that vulnerability of farmers in most developing countries is compounded by factors such as widespread poverty and weak financial and structural capacity (Jennings and Magrath, 2009).

In furtherance to the assertion by Jennings and Magrath (2009), Lyimo and Kangalawe (2010) noted that the vulnerability to climate change and variability of local communities are among other aspects influenced by livelihood assets (Social, physical, financial and natural assets). The more assets people have, the less vulnerable they are. On the contrary, the greater the wearing down or less assets people have, the greater their vulnerability (Gbetibouo and Ringler, 2009). These factors influence farmers' production decisions; for instance, they force farmers to choose low-yield, low-risk inputs instead of highly productive and profitable inputs, leaving them unable to adopt new technologies (Kelbore, 2011). This, in turn, results in lower yields which translate into lower incomes and acts as a stumbling block against poverty alleviation.

2.5 Adaptation by Food Crop Farmers to Climate Variability

According to the IPCC (2007), adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. The propensity of systems to adapt is influenced by certain system characteristics that have been called "determinants of adaptation" in the literature (IPCC 2007). These include terms such as "sensitivity," "vulnerability," "resilience," "susceptibility" and "adaptive capacity" (IPCC, 2007). The occurrence as well as the nature of adaptations is influenced by these factors (Olmos, 2001). For effective adaptation to be possible there must be clear distinction between the various factors. Sand (2012) believes that increasing and enhancing adaptive capacity symbolizes a pragmatic means of coping with changes and uncertainties in climate, which will reduce vulnerability and facilitate coping and adaptation among farmers. In this regard, a very comprehensive view of evaluation of these terms will bring to light best practical adaptation options.

Adaptation to climate variability or change occurs at multiple levels, from the smallholder farmer to community, national and even global level (Challinor *et al.,* 2007). This is because some types of adaptation are best implemented at the government or institutional level, community level and farm level. According to Khan (2009) and Rickards and Howden (2012), engineering and technological adaptation measures such as planting of biofuel crops and improved seeds, conservation of bio resources through biotechnology and agro biodiversity are best implemented at the government or institutional level. However, it is important that technology-based adaptation measures must be tailored to the circumstances of the problem by considering the characteristics of the vulnerability, climate type and the socio-cultural environment of the people (Nyantakyi-Frimpong, 2013) to help address some of the challenges. At the government level, meteorological/climate information and forecast contribute to agricultural planning (Cardoso *et al.,* 2010).

Some studies indicate that the availability and accessibility of climate information and forecasts will help farmers to make strategic decisions concerning their farm operations (Challinor *et al.,* 2003). For instance, climate forecasts have been made and utilised since, at least, 1991 in the Nordeste region of Brazil, where persistent periodic droughts have caused great hardship for poor smallholders and landless peasants. Warnings were issued in the capital of Ceará, Fortaleza, of potentially severe water shortages; this led to 18 % fall in grain production in 1992 as compared to 85% fall in1987 when climate forecasts were not applied (Kabat *et al.,* 2002).

Perhaps, inadequate information on climatic conditions and climate predictions in Ghana are major setbacks in crop production. What has been realized in the country is that the government is quick to respond to damages caused by extreme climatic events than making farmers aware and prepare for disasters. There is the urgent need to shift from response and recovery to awareness and preparedness (Thomalla *et al.*, 2006 cited in Mudombi-Rusinamhodzi *et al.,* 2012). Based on that, it is important to take into consideration weather monitoring and forecasting for effective disaster and adaptation planning. Much work is, therefore, needed on the applicability of weather monitoring and forecasting on crop production as effective adaption planning.

In addition, other international conferences have argued for integration of adaptation strategies into national policies. For instance, the Hague Conference in 2010 proposed that governments can better integrate targets for agriculture in national plans for adaptation to ensure sustainable agricultural development (Beddington *et al*., 2012). Sustainable agricultural practices according to Lipper *et al.* (2010) include diversified rotations (including crop varieties and species with different temperature requirements), improved nutrient and water use efficiency, resistance to pests and disease, conservation agricultural and lower yield variability. Other practices include farm forestry, agro-forestry or evergreen agriculture, and minimum tillage to reduce soil erosion and increase the soil's capacity to hold water and sequester carbon dioxide (Parry *et al.*, 2009).

All these agricultural practices outlined require capital investment. However, Vidal (2009) has observed that government support that would help poor farmers in most developing countries to adapt to climate variability and change is very limited. In addition, developing countries have received less than 10% of the money promised by rich countries to help them adapt to global warming (Vidal, 2009). These problems have crippled most governments in their attempt to implement adaptation strategies. Given limited resources to finance adaptation actions, a government's top priority should be appropriately targeted to those whose livelihoods are more vulnerable. However, as a general rule, most developing countries have largely failed to target those whose livelihoods are more vulnerable. In the face of these challenges, governments and other stakeholders can buy into smallholder crop insurance scheme for the most vulnerable which has been successfully implemented in India (Thornton *et al.,* 2014).

Due to the inadequate support from government, farmers in their own ingenuity have developed their own traditional methods and techniques of adapting to climate variability at the farm level (Batterbury, 2004). Simbarashe (2013**)** observed that these traditional knowledge and indigenous knowledge systems have been extremely useful to both adaptation and mitigation strategies devised by smallholder farmers. For instance, some farmers in Bikita and Nganyi in Zimbabwe and Northern Ghana respectively use traditional methods of weather forecast like behaviour of plants and animals to predict weather conditions and decide when to prepare lands and sow seeds (Roncoli *et al.,* 2002; cited in Antwi-Agyei *et al.,* 2013 and Guthiga and Newsham, 2011; cited in Nyantakyi-Frimpong, 2013). These indigenous knowledge make it possible for farmers to adequately prepare in advance for any climatic catastrophe.

According to Nyantakyi-Frimpong (2013), these traditional coping strategies are largely based on experiences that have been accumulated over the years and transmitted from one generation to the other. The traditional coping strategies can be improved upon through proper and systematic planning and rendering technical assistance by extension officers (Batterbury, 2004). However, many policy makers remain uncertain on the reliability of indigenous knowledge, considering it as inadequate basis for sustainable agricultural practices (Nyantakyi-Frimpong, 2013). Other traditional coping strategies commonly employed by farmers include adjustment in planting dates, mixed cropping, crop rotations and cultivars adapted to different moisture conditions (reducing the risk of complete crop failure), using landraces resistant to climate stresses, mulching, water conservation and rain harvesting techniques (Stanturf *et al.*, 2011). Some farmers also find relief by engaging in small-scale irrigation. Crop irrigation, according to Nyantakyi-Frimpong (2013), has seen some success, and it is argued by some that it should be more widely implemented. The portrait of smallholder farmers presented in these examples is one of resourcefulness and resiliency.

Thornton and Lipper (2013), and Di Falco and Chavas (2009) also identified diversification as a viable strategy for farmers to resist shocks, decrease the risk of crop failure and in so doing reduce vulnerability of farmers' livelihood to climate variability. Thornton and Lipper (2013) categorized diversification into crop and livelihood diversification. Among the categories, Kandulu *et al.* (2012) and Simbarashe (2013) classified crop diversification as the most beneficial in "intermediate" conditions and drought prone areas. Livelihood diversification implies that farming households are involved in more and different non-agricultural activities. Lansigan *et al.* (2000), identified on-farm and off-farm employment opportunities as essential multiple livelihoods activities to ameliorate vulnerability of farmers. These multiple livelihood opportunities according to Khan *et al.* (2009) are essential not only as reasonable take-home but also as an insurance mechanism.

In Ghana livestock rearing primarily in the Northern Savanna Zones, appear to be a viable livelihood diversification strategy for food crop farmers. However, grazing rights tend to create conflicts, particularly if land tenure and rights are unclear (Stanturf *et al.*, 2011). Non-farm income earning activities also offer opportunities for diversification when agriculture becomes more risky. For instance, in a study of 11 Latin American countries, the results show that, non-farm income accounted for 40% of rural household incomes, indicating how essential income generated from this source is to farmers (Barret *et al.,* 2001; cited in Antwi-Agyei *et al.,* 2013). The idea of livelihood diversification activities is very laudable; however, it requires some financial assistance and sometimes little training to ensure its sustainability.

In addition to livelihood diversification, some farmers embark on seasonal migration or travel to distant places for work (Batterbury, 2001, Mortimore and Adams, 200; cited in Kandji *et al.,* 2006). This is common in sub Saharan Africa as a result of rapid urbanisation and improved mobility in the region. It is important to note that, the strategies most farmers adopt have their own limits especially when extreme climatic events become more persistent. Nevertheless, these strategies have helped rural farmers to withstand some of the pressures posed by climatic variability (Kandji *et al.,* 2006). From the foregoing, it is not just identifying the right technologies or practices that will result in successful adaptation, the mechanism that will compel sustained adaptation and revolution of agricultural systems are innovation of all forms (social, institutional, technological and indigenous knowledge). There is therefore the need to develop a common platform at the national, community and farm levels for coherent dialogue and policy actions related to climate variability and food crop production. This is an essential ingredient to ensure sustainable adaptation strategies (Thornton and Lipper, 2013).

2.6 Theoretical Underpinnings of the Study

The capability theory is a broad normative framework that attempts to address various concerns about contemporary approaches to the evaluation of well-being (Kronlid, 2014). The Capability Approach measures the extent of a person’s substantive freedom (the opportunities and choices that are actually available to them) to achieve a valuable functioning (Mackenzie *et al.,* 2014). Sen (1999; cited in Mackenzie, 2014) argues that functions represent the various things a person is able to do. The Capability Approach (CA) has been adopted as a theoretical tool because the work of Amartya Sen provides a strong theoretical basis and a vibrant societal picture to describe individual's well-being. The CA has also been adjusted to focus on inequality, social justice, living standards, rights and duties, among other things. According to Robeyns (2005; cited in Kronlid, 2014), Sen's work has found a wide significance in a number of academic disciplines, has been applied across many social settings and has influenced the United Nations Millennium Development Goals and Human Development Index.

The core characteristic of the capability approach is its focus on what people are effectively able to do and to become, that is, their capabilities. Though, the core actor of the theory is the individual capabilities, however, it also emphasizes on the role of policy makers in assisting the individuals in enhancing their competence. As Sen (1999; cited in Mackenzie *et al.,* 2014) points out, many important freedoms are made possible by well-designed public policies and well-functioning institutions. Such policies and institutional structures according to Mackenzie *et al*. (2014) enable individual freedom and autonomy to promote resilience and avert vulnerability.

Several studies have come out with how climate change/variability pose challenges to individuals and communities. Since the capability approach addresses the core value of human life to function, the challenges posed by climate variability affect what individuals are capable of doing with the assets or resources they have. In the face of these challenges, the capability theory allows us to assess how climate variability and extreme climatic events affect individual freedoms, how adaptation actions may be instrumental to the expansion of capabilities, how adaptation actions and strategies may hinder or preclude being (Various state of human being existence) and doings (functions) and how these beings and doings may be ethical limit to climate change (Kronlid, 2014). According to Sen (1999; cited in Roy and Venema, 2009), there are five influential freedoms (political freedom, economic facilities, social opportunities, transparency guarantees and protective security) that if individuals have access to, will provide opportunities for them to act in their own self-interest and reduce vulnerability. Access to these freedoms is necessary for farmers to acquire the capabilities they need to reduce their vulnerability to climate variability and extreme events.

Drawing on the understanding of the capability theory, Klinsky and Winkler (2014) were of the view that, the capability approach as it applies to climate equity, rests on sufficient mitigation and adaptation actions and climate policies. According to them, sufficient mitigation and adaptation actions on one hand, addresses the direct impact of climate change on people's capabilities particularly those of the vulnerable. The climate policies on the other hand, addresses the effects that climate policies can have on human capabilities. Taking together these two pillars proposed by Klinsky and Winkler (2014), the capability theory will provide a basis that would encourage policy makers to build a long term human capabilities and adaptation strategies. From this, the theory appears to have a significant value on farmers' adaptive capacity and addresses the issue of their vulnerability to climate variability.

Nonetheless, the capability approach is threatened by specific capability deficit. Such capability deficit can signal sources of occurrence or dispositional vulnerability. The notion of vulnerability also signals the actual or potential harm that may result from a particular capability's deficit and highly hit the obligation to address those deficits in order to remediate vulnerability (Mackenzie *et al.* 2014). This simplifies O'Brien *et al.*'s (2004) interpretations of vulnerability as both "end and starting point." Notwithstanding the position of Mackenzie *et al.* (2014), this study supports the views of Klinsky and Winkler (2014) and Roy and

Venema (2009) that capability theory can be a tool to identify obstacles which thwart the individual's ability to adapt to climate variability.

2.7 Conceptual Framework

Advances in technologies have enabled humanity to create artificial microclimates, breed plants and animals with desired characteristics, enhance soil quality, and control the flow of water (FAO, 2008). This has made it possible for farmers to cultivate and harvest hefty quantities of crops at reasonably low cost. In spite of this, food production performance still depends more on climate. Consequently, seasonal variation or climate change has significant impacts on food security (FAO, 2008). In the quest to understand the impacts of these seasonal variation or climate change on food security, the Climate Change and Food Security (CCFS) framework (Figure 2.3; page, 36) was developed by the FAO in 2008 to provide information on the interrelationships between climate change and food security (food availability, food accessibility, food utilization). The framework takes a broader view and explores the multiple effects that global warming and climate change would have on food systems and food security. The framework also suggests strategies for mitigating and adapting to climate change in several key policy domains of importance for food security. The framework focuses on the projected effects of the current incidence of human-induced global warming on the climate system now and for the next several decades.

The climate change variables considered in the CCFS framework are:

- The CO_2 fertilization effect of increased greenhouse gas concentrations in the atmosphere
- Increased global mean temperatures
- Gradual changes in precipitation
- Increase in the frequency and intensity of extreme weather events
- Greater weather variability

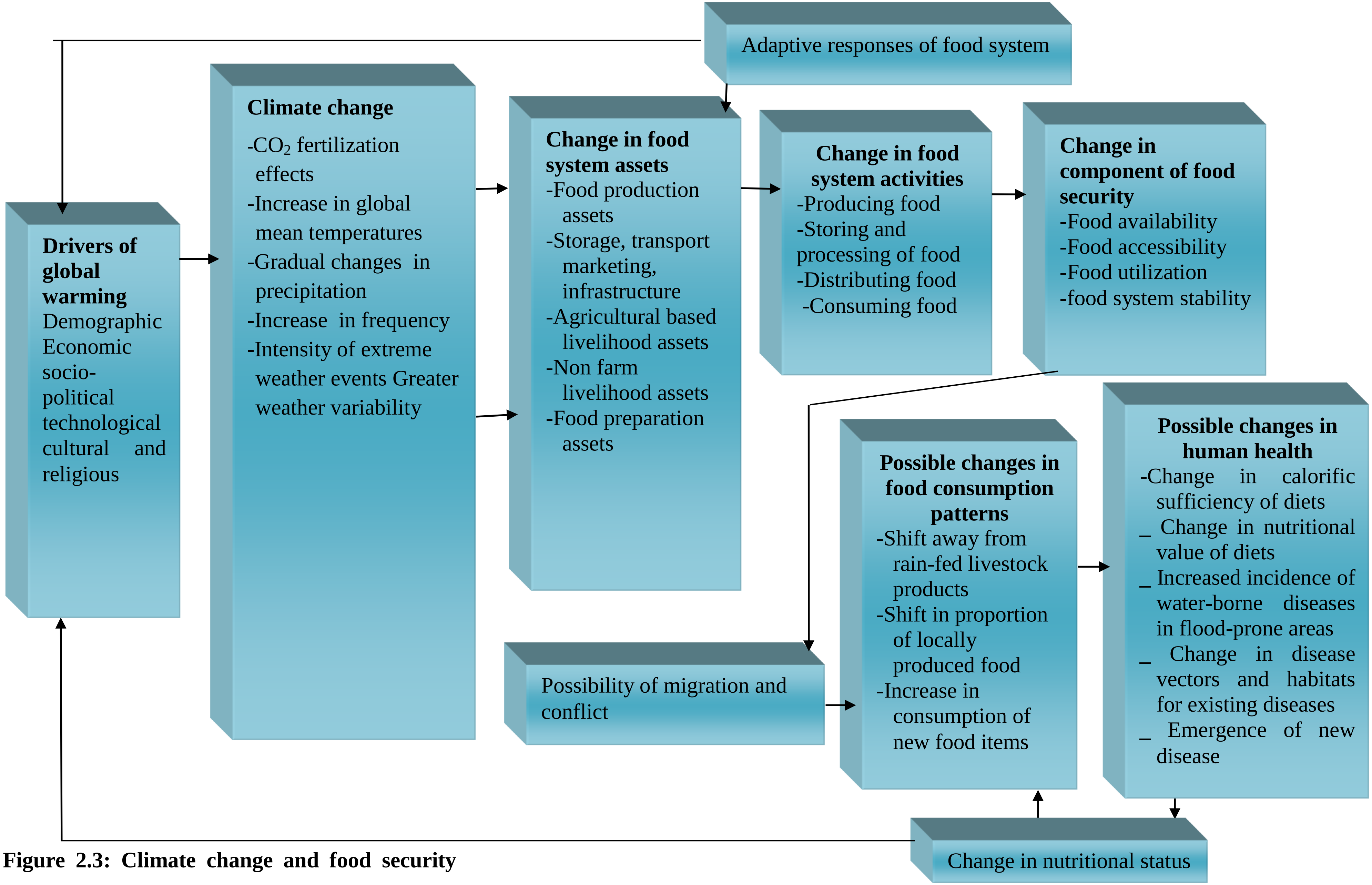


Figure 2.3: Climate change and food security

Source: FAO (2008:10)

Calorific Evidence available indicates that the variables considered in the framework are already having immediate impact on food production, as well as food distribution, infrastructure, incidence of food emergencies, livelihood assets and human health in both rural and urban areas (FAO, 2008). The framework illustrates how the drivers of global warming influence the climate change variables. The elements which make up the drivers of global warming include demographic, economic, socio-political, technological, cultural and religious.

Notwithstanding the above, the framework has given the world a complete and comprehensive view about the impacts of climate change on food security. In totality, the goal of the FAO's climate change framework is to inform and promote both regional and local dialogue about what the impacts of climate change are likely to be and what options exist for reducing vulnerability, and to provide local communities with site-specific solutions to prevent any future predicament of climate change (FAO, 2008). The framework is modified as a key point of reference for the purpose of this study. The adapted version is used in examining the effects of climate variability on food crop production. It also attempts to identify the potential positive effects of climate variability on food crop production and how the adaptive responses and the possible positive effects will translate into sustainable development of food crop production. The study draws on ideas from the works of the FAO, IPCC, among others. Figure 2.4 (Page 38) shows the factors that result in climate variability taking into consideration both natural factors and anthropogenic factors and how they influence crop production. The framework highlights nine interacting elements: that is, drivers of global warming, climate variability, effects on food crop production, positive effects, negative effects, adaptation strategies, vulnerability of food crop farmers and sustainable development of food crop production.

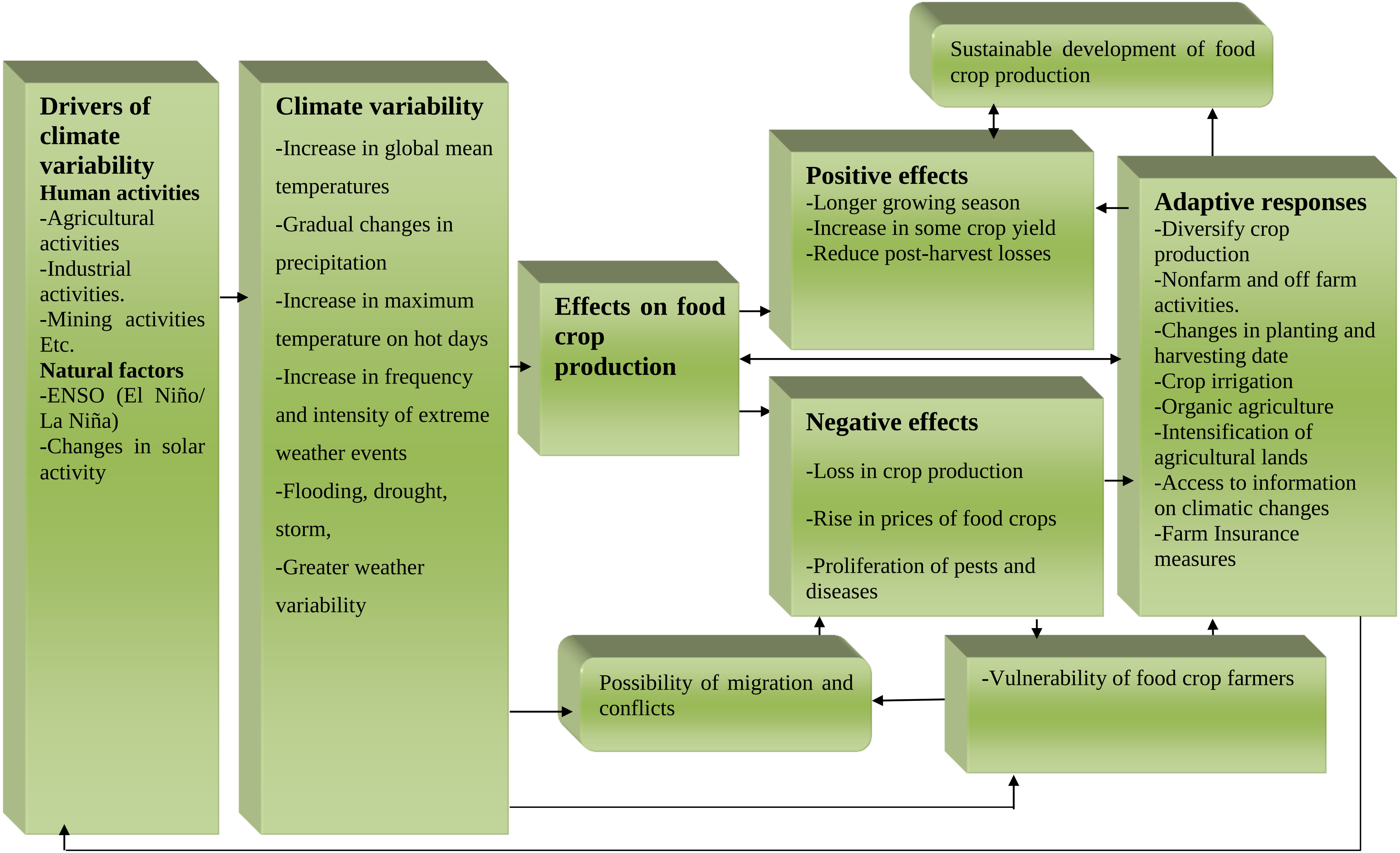


Figure 2.4: Climate variability and food crop production

Source: Adopted and modified from FAO (2008)

The doubled-edged arrows which link some of the components highlight the dynamic and interactive nature of climate variability and food crop production. Thus, these components affect and are also affected by the components. The framework is dependent on climate variability on which the development of agriculture and livelihoods of farmers are affected. The degree of the effects of climate variability on food crop production depends on the extent of climate variability and how effectively food crop farmers are able to adapt to the situation.

The framework depicts the warming of the world caused by both natural forces over which humankind has no control and anthropogenic forces. According to the FAO (2008), the warming of the earth is regulated by the radiation of the earth's energy, which is subjected to some level of changes. But most of these changes occur on astronomical or geological time scales. Climate variation on these scales is sometimes referred to as "climate variability". El Niño Southern Oscillation (ENSO) is a strong driver of this climate variability that greatly impacts agricultural activities (Legler *et al.*, 1999; cited in Cabrera *et al.*, 2009). However, human activities such as agriculture, industrial and mining activities have intensified the release of the natural greenhouse gas thereby increasing the concentration of the GHGs in the atmosphere. This has resulted in temperature increases and has affected global precipitation (FAO, 2008). This implies that climate variability occurs naturally although increases in the concentration of greenhouse gases in the atmosphere as a result of human activities have further increased the intensity of climate variability.

Due to the impacts of anthropogenic activities on the environment, numerous researches on climate variability and change have theorised that, a decrease in rainfall coupled with high temperature will turn dry areas drier resulting in severe drought in some parts of the world. This could reduce or shorten the length of the growing season, while an increase in rainfall will cause an increase in flood intensity and frequency. Regions that see extensive rainfall will get even more while arid regions will dry out (Watts, 2012). This hypothesis is being experienced in some parts of the world. The combination of these extreme increases and decreases of climatic conditions will virtually result in the proliferation of pests, pathogens and vanishing pollinators (Epstein, 2005). This will have a negative implication on crop yield.

For instance, it is believed that one fungal disease, soybean rust, was ushered into the United States by Hurricane Ivan in September 2004, affecting soybean production in the United States (Pan *et al.*, 2006). Such seasonal variations in food crop production, along with vulnerability to flooding and drought can make livelihoods more vulnerable at certain times of the year. Although these impacts might appear indirect, they are important because many marginal livelihood groups are close to the poverty margin, and food crop production is a key component of their existence.

Income of small scale farmers who are not protected by insurance may decline sharply if there is a market glut or if their own crops fail and they have nothing to sell. This will have severe short term and long term impacts on households. Over time, farmers' vulnerability to climate variability may worsen (FAO, 2008) and this will have adverse effects on their livelihoods.

Generally, the adverse impacts of climate variability and change on agricultural activities in rural communities are more likely to be felt as loss of employment for farm workers, reduction in wage earnings, loss of purchasing power for agricultural wage workers and decline in crop yield for household consumption. These in many cases drive rural urban migration which provides an opportunity for rural farmers and other farm workers to improve upon their livelihoods (FAO, 2008). Thus, with increased vulnerability some farmers and farm workers will have to migrate to other places to make a living.

Indirectly, prolonged and repeated droughts are likely to create competition between herders and food crop farmers and this has the potential to result in conflicts. A typical example was experienced in the Sahel, when many Fulani migrants were forced to move to Ghana to pursue pastoral livelihoods around the Volta Basin (Tonah, 2006). Pockets of such conflicts are being experienced in some parts of southern Ghana. If climate variability results in greater aridity, it is likely to intensify these conflicts. Some studies suggest that conflicts between herders and farmers in recent times have become more violent. Given current conditions of the savannah zones in Burkina Faso, the northernmost and some parts of southern Ghana, this may occur regardless of the climatic condition (FAO, 2008).

The level of effects of the extreme weather events will result in farmers identifying options to adjust to the variability of the climate to ameliorate the negative effects. In their quest to survive, farmers will have to diversify their sources of revenue by engaging in non-farm or off-farm activities to supplement their farm wages (Zorom *et al.*, 2013). According to Scoones (2009), non-farm activities help people to cope with temporary adversity in the agricultural sector and also represent a longer-term adaptation strategy when other options fail. However, climate variability may pose problems for non-farm activities that are natural resource-based. For example, declines in tree cover will make it more difficult to engage in charcoal production, the sale of firewood, and the gathering and manufacture of products from some non-timber forest species such as the dawadawa and shea trees, despite the protected status of these trees in many communities. Furthermore, farmers will have to resort to other farming practices such as organic agriculture (application of manure and chemical fertilizer) and agriculture intensification. Moreover, some farmers will have to cultivate crops that are resilient under drought stress or in poor quality soil or diversify their crops. Some of the more staple crops can be cultivated along with an insurance crop in case of crop failure.

This would reduce food insecurity and buffer the financial implications of unexpected crop failure following extreme events (Garrido *et al.*, 2011).

With increased variability, information about climatic changes will have to be provided to farmers in order to effectively adjust to planting date and also promote practical adaptation. Additional awareness about unfavourable climatic conditions through the media is likely to become more common for farmers. This implies that at the national level, governments will have to invest in climate research and disseminate information to increase awareness of climate variability and its impacts and also strengthen the capacity of policy makers and institutions to effectively use climate information for development planning and to make informed decisions that will consider climate risk.

In flood prone areas and regions where torrential rain is very common, governments can partner stakeholders and other private institutions to invest in large scale irrigation and water harvesting technology. This in the long run will help mitigate the danger that farmers face during flooding and prolonged drought (FAO, 2008). Alternatively, farmers can plant trees to procure some shading on the soil to prevent erosion. This can be done if there is adequate climate information. With the aid of technology, there would be improved land management practices which would contribute to soil moisture retention, maintain appropriate amount of nutrient in the soil, strengthen resilience and enhance productivity (FAO, 2008). Looking at the multifaceted nature of the effects of climate variability on food crop production, any intervention aimed at either mitigating the negative effects or developing adaptation strategies must be through involvement of the farmers and this would indirectly educate or inform them on appropriate strategies. The interventions must clearly seek to establish the association between multiple strategies and those that are environmentally friendly (IPCC, 2012).

However, in the attempt to upgrade crop production through adaptation strategies, it would further contribute to increased climate variability, thus acting as an agent of climate variability. For instance, it is clear from the analysis by DeAngelis *et al.* (2010) that the increase in irrigation across a large-region of the Great Plains may have contributed to the increase in summertime precipitation, especially July precipitation, which showed an increase of 15–30% in a broad region. This according to them, is consistent with their hypothesis that the Ogallala irrigation may have enhanced the regional precipitation.

Notwithstanding the adverse effects of increased temperature and rainfall variation on crop production, some areas will experience an increase in crop yield. The FAO (2008) hypothesised that, increase in local temperatures and shifts in rainfall have some positive effects such as longer growing season and warmer nights. This will benefit some crops especially those that thrive well in the heat. This could increase crop yield in the dry season. This hypothesis is supported by a research conducted by Cabas *et al.* (2010) in South Western Ontario. They found out that although precipitation and temperature variability may have a negative impact on crop yields, average yields will be higher in the future due to longer growing season. This will offset the negative effects. Again, the consensus of scientific opinion is that countries in the temperate, high and mid-latitude regions are generally likely to enjoy increased agricultural production (Arnell *et al.,* 2002; Devereux and Edwards, 2004; cited in Ziervogel *et al.,* 2006). On the contrary, if the conditions become far too challenging, then farmers may see less of a scope for investment, and they might be forced out of agriculture and migrate with very important implications on their livelihoods (FAO, 2008).

It must be emphasised that the range of adaptation options and policies have the potential to ensure sustainable development in food crop production. According to the IPCC's Third Assessment Report, "adaptation to current climate variability and extremes often produce benefits as well as forming a basis for coping with future climate change. Policies that lessen pressures on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, enhance adaptive capacity, and reduce vulnerability to climate and other stresses. Inclusion of climatic risks in the design and implementation of national and international development initiatives can promote equity and development that is more sustainable and that reduces vulnerability to climate change" (IPCC 2001: 8).

2.8 Chapter Summary

Reliable climate records have been kept for many regions of the globe over the last 100 years. Since the 19th century the mean global surface temperature has increased by between 0.3°C and 0.6°C signifying considerable variability. As a result, there has been an increase in the frequency of storms, with heavy precipitation over most land areas in the world (Lobell *et al.,* 2011). Peoples' subjective observations of climate may be confirmed by statistical data, but extreme events may sometimes be interpreted as a confirmation of ongoing human induced climate variability (Meze-Hausken, 2004**)**. Many research findings confirm that agricultural performance is decreasing, and that the influence of climate variability is the main cause of regress in productivity. In spite of food production being a lucrative business, it is full of uncertainties mostly caused by climate variability. This results in significant fluctuations in crop yields and productivity, exposing food crop famers to economic hardship. In view of that farmers have to develop mechanisms to adapt to the uncertainties. It should be underscored that the ability to adapt and cope with climate variability hazards depends on economic resources, infrastructure, technology, and social safety nets (Slater *et al.*, 2007 cited in Simbarashe, 2013).

CHAPTER THREE

RESEARCH METHODOLOGY AND PROFILE OF THE STUDY AREA

3.0 Introduction

This chapter provides information on how the study was carried out to achieve its objectives. In addition, a description of the study area is presented. The chapter is organised into two main sections. Information on the research approach, research design, sources and types of data, sampling techniques and the process by which information was collected and analysed are presented in the first section. The second section describes the location and demographic characteristics of the study area within which the selected communities fall. Information on vegetation, climate, geology and economic activities are also presented.

3.1 Research Methodology

3.1.1 Research approach

The study employed the triangulation approach which quantitative methods were combined with appropriate qualitative methods (Sandelowski, 2000).The purpose was to ensure reliability (the extent to which results are consistent over time) and validity (the means of which measurements are accurate) of the research. Sandelowski (2000) elaborates that an integrative methodological approach controls bias and ensures validity and reliability of research findings. The survey was responded to by farmers in the Bawku Municipality and officials from the Ministry of Food and Agriculture (MoFA), Savanna Agricultural Research Institute (SARI) and Ghana Meteorological Agency (GMA) in Bawku.

3.1.2 Research design

A cross sectional and time series study designs were adopted to explore the effects of climate variability on food crop production and to identify farmers' vulnerability and adaptation to climate variability. A cross-sectional study is where variables are measured or determined at the same time in a given population (Olsen and George, 2004). Olsen and George (2004) further state that, cross-sectional study is useful in assessing the practices, attitudes, knowledge and beliefs of a population in relation to a particular event or phenomenon. Cross-sectional survey was therefore used to assess farmers' perceptions, vulnerability and adaptation to climate variability. Time series study was used to analyse the influence of climatic trends on crop production because the study again examined past observation of climate variables (temperature and rainfall) and crop production.

3.1.3 Types of data

The study employed both qualitative and quantitative data to avoid the shortcomings of basing the findings and conclusions on a single type of data. This was to help achieve a high degree of validity and reliability. Information obtained from food crop farmers, historical data for climatic variables (rainfall and temperature) and food crop production formed the basis of the quantitative study while information obtained from officials of the SARI, MoFA and the GMA formed the basis of the qualitative study.

3.1.4 Sources of data

The quantitative and qualitative data were obtained from both primary and secondary sources. The primary data were collected from food crop farmers, officials from SARI, MoFA and GMA in Bawku. The primary data elicited information on the socio-demographic characteristics of respondents, observed changes and variability of climate and its effects on food crop production and, adaptations and vulnerability of food crop farmers to climate variability. The secondary data were obtained from articles, journals, reports and documents from government departments and institutions (MoFA, GMA, and SARI) pertaining to climate variability and food crop production to validate the primary data.

3.1.5 Sampling technique and selection of communities

Bawku was purposively selected as the study area based on its vulnerability to climate variability (Amikuzuno and Donkoh, 2012). Five communities were selected from the Municipality. With the technical assistance of the Director of MoFA, *Mognori*, *Zabugu*, Gozesi, *Kuka* and *Gentiga* were selected. The selection of these communities was partly based on the intensive farming that is done by the farmers during the rainy season and the dry season and partly by the high production of staple foods in these communities compared to other communities in the Municipality.

The study made use of the simple random and purposive sampling techniques to select the respondents. The simple random sampling was used to select households in the selected communities. The study used the simplified formula for sampling provided by Yamane in 1967 (Kasiulevičius *et al.,* 2006) to identify the appropriate total respondents in each community. The formula is presented as:

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

Where, e = Deviation of Sampling,

N = Population Size and

n = Sample size

This formula is reliable at 95% and less than 5% variation factor (Kasiulevičius *et al.*, 2006). The sample frame of the study consisted of the total household population of the five communities (247) as released by the Planning Department of the Bawku Municipality. A sample size of 214 households was sampled from the sample frame. The sample size of each community is presented in Table 3.1 (Page 48)

Table 3.1: Population and sample characteristics of selected communities

Community	Population	Total Number of Households	Sample Size from selected Community
Mognori	952	61	51
Zabugu	1021	66	55
Gozesi	806	52	47
Kuka	550	35	31
Gentiga	521	33	30
Total	**3,851**	**247**	**214**

Source: GSS, 2010

The respondents consisted of food crop farmers who have lived in the selected community and have been engaged in farming for at least 25 years. The essence was to discover past and present situations of crop production in relation to climate variability. In addition, three officials each from MoFA, GMA and SARI were purposively selected and interviewed for additional information. The purposive sampling technique was used to select farmers for focus group discussions. The purposive sampling technique was again used to select one farmer with long experience (between 50 and 60 years) in farming in each of the community to obtain his/her livelihood histories.

3.1.6 Method of data collection

Based on the objectives of the study, the triangulation method was employed. Thus, more than one method was used in collecting data for this study. According to Yeasmin and Rahman (2012), multiple methods minimise the inadequacies of a single method. The use of triangulation therefore enabled some checks on information provided by means of a particular approach. The primary data were collected using questionnaires, focus group discussions, structured interviews, field observations and oral narratives.

The questionnaires were administered to food crop farmers and the administration was by face to face interactions. The respondents were briefed on the purpose and relevance of the study before the administration of the questionnaires. Households were the key units of analysis. Households were defined as a group of people living and sharing meals cooked from one pot and taking individual and collective decisions within domestic units. This excludes family members living elsewhere (Preston, 1994 cited in Brook and Davila, 2000).

One focus group discussion was carried out in each community to generate conversations that uncover individual opinions regarding the effects of climate variability on food crop. The focus of the discussions was to explore the effects of climate variability on food crop production. Each focus group was made up of a minimum of eight participants and a maximum of ten. The participants were randomly selected from the communities with the help of community leaders, and one official each from MoFA, GMA and SARI. This was to help identify trend and variation in the perceptions and opinions expressed by the participants of the selected communities. The researcher facilitated the discussions using a checklist prepared for the purpose. The discussions were recorded and transcribed by a research assistant.

Structured interview guides were employed to obtain additional information from officials of MoFA, SARI since they work directly with the farmers in the Municipality and GMA. The purpose was to explain and verify the findings obtained from the administration of the questionnaires.

Field observation was employed to capture the social setting of respondents and the influence of the physical environment on the activities of the respondents. This was to provide insight into the interaction between respondents and their physical environment and also ascertain the realities on the ground.

Oral narrative was also employed to reveal livelihood histories of food crop farmers in relation to climate variability in each selected community to discover the extent of historical dimensions of farmers' vulnerability to climate variability. This was to help provide insight into how climate variability and past extreme climatic events have affected the livelihood activities of farmers (Sallu *et al.,* 2010).

The study relied on documented records of monthly observations of climate variables compiled by the GMA for a period of 15 years. The use of a 15 year data was considered as adequate because consistent collation of data over periods of 15 years or more according to Hochman *et al.* (2013), provides a useful quantification of putting across the unpredictability of crop yields in relation to climate variability. Temperature and rainfall data were used to constitute the climatic variables since they are the main climate variables that greatly influence crop yield (IPCC 2007 and FAO, 2008). More so, production data on major food crops (maize, millet and rice) in the study area from 1999 to 2013 were also obtained from MoFA in Bawku for analysis. In addition, data on soil fertility in the Bawku Municipality over the period under investigation was obtained from the Soil Research Institute (SRI) in Kumasi.

3.1.7 Data analysis and presentation

The quantitative data obtained from the farmers were processed and analysed using descriptive statistics. Microsoft Excel was used to generate frequency tables, cross tabulations, bar graphs and pie charts to facilitate easy understanding and interpretations. Time series analysis was used to examine the trend in annual maximum and minimum temperatures as well as rainfall in the past 15 years (1999 to 2013). The magnitude of the trends of the climate variables were tested by the Mann-Kendall trend test. Variability of rainfall, temperature and food crop production were analysed using coefficient of variation. Coefficient of variation is a statistical measure of how the individual data points vary about the mean value (Akpan *et al.,* 2013). This was determined by dividing the standard deviation by the mean.

Multiple regression model (Ordinary Least Square procedure) was used to test the hypotheses and analyse the influence of the mean annual temperature, total annual rainfall, soil fertility on three major food crops (maize, millet and rice) over the 15 year period (1999 to 2013). The multiple regression model has been widely used in analysing the effects/impacts of climate variability/change on food crop production (Rowhani *et al.*, 2011 and Tunde, 2011). The use of multiple regression equation was motivated by the fact that it allows modelling relationship between two or more explanatory variables and a response variable. The correct use of the multiple regression model requires that several critical assumptions must be satisfied in order to apply the model and establish validity. Multiple regression assumes that variables have normal distributions, homoscedasticity and serially uncorrelated errors. The violation of these assumptions may lead to bias in test statistics and confidence interval which will contribute to wrong validity of estimates (Antonakis and Deitz, 2011 cited in Ballance, 2011). To satisfy the assumptions of the multiple regression model, the test for normality, heteroscedasticity (having different variances) and serial correlation or autocorrelation (the relationship between observations on the same variable over independent periods of time) were conducted using Jacque-Bera, Breusch-Pagan-Godfrey test and Breusch-Godfrey Serial Correlation LM Test respectively.

Soil fertility (Soil pH and Organic Matter) was considered as a control variable for the study. This was to determine how other variables that were not included in the study affect food crop production. The use of soil fertility as a control variable stems from the fact that soil is a medium for plant growth and crop growth variability has been attributed to soil fertility (Van Asten, 2003; Chakraborty and Mistri, 2015). This is because soil fertility is the intrinsic capacity of soil to provide essential plant nutrients in adequate amounts to ensure optimum plant productivity (Basak, 2000 and Singh, 2006; cited in Chakraborty and Mistri, 2015).

Soil pH was used as a proxy for soil fertility in rice production and organic matter as a proxy for soil fertility in millet and maize production after a correlation analysis was performed (See appendix I) on the components of soil fertility (soil pH, organic matter, nitrogen and phosphorus). The results of the correlation showed that soil pH was positively correlated with rice production while organic matter was positively correlated with maize and millet production. Soil pH and organic matter were therefore considered as proxy for soil fertility for the major food crops in the Bawku Municiaplity. The level of significance for the study was set at 0.05. The linear regression model used was similar to the model used by Onoja and Ajie (2012) to analyse food crops' response to climate variability and micro economic policies reforms in Nigeria.

The model is presented as:

$Y = \beta o + \beta_1 X_i + \beta_2 X_i + \beta_3 X_i + ... + \beta_k X + \mu_i$:……………………………………………1

Where Y is the dependent variable; X is the independent variable whiles μ is the stochastic error term and βo being the intercept of the model. Natural logarithms of the variables were taken to strengthen out exponential growth pattern and reduce the potential heterogeneity of variance of error terms; that is, to stabilize variance (Akpan *et al.*, 2013).

$LnRice_i = \beta o + \beta_1 lnRAi + \beta_2 lnTEi + \beta_3 lnSPH_i + \mu_i$ ……….. Linear Model …………….2

$LnMillet_i = \beta o + \beta_1 lnRA_i + \beta_2 lnTE_i + \beta_3 lnORG_i + \mu_i$…………………………………....3

$LnMaize_i = \beta o + \beta_1 lnRA_i + \beta_2 lnTE_i + \beta_3 lnORG_i + \mu_i$……………………………………4

Where, RA= Annual rainfall in millimeters in the Bawku Municipality, TE= Mean annual Temperature in °C in the Bawku Municipality; SPH= Soil pH; ORG= organic matter μ = stochastic error term; β o = intercept of the model.

The qualitative data obtained from focus group discussions and structured interviews were recorded and analysed thematically based on different responses, and used as vital elements of written text to better understand farmers' vulnerability and adaptation strategies to climate variability. In addition, it was used to authenticate the findings of the quantitative data analysis. The oral narratives by the food crop farmers were transcribed and recapitulated to form their livelihood histories which were used as a fertile source to further demonstrate farmers' vulnerability to climate variability and extreme climatic events. Using photographs as a means of presenting data is an important way of trying to show data in its natural setting (Yeboah, 2008). According to Clancery (2001 cited in Yeboah, 2008), it is the best means of recording, keeping and presenting data. The use of photography in presenting data or supporting data analysis was found to be essential to this study. This technique was therefore chosen for data presentation.

3.2 Profile of Study Area

3.2.1 Description of location and demographic characteristics of the study area

The Bawku Municipality is located in the extreme north- eastern part of Ghana and is one of the two Municipalities in the Upper East Region of Ghana. It lies between latitudes 10° 40^{1} and 11° 11^{1} North of the Equator and longitudes 0° 18^{1} W and 0° 6^{1} East of the Greenwich Meridian. The Bawku Municipality has a total land area of about $247.23720km^{2}$. The Municipality is bounded to the north by Burkina Faso, to the south by the Garu-Tempane District, Binduri District to the west and to the east by Pusiga District (Ghana Statistical Service, 2014). Figure 3.1 (Page, 54) shows the study area in the national context while Figure 3.2 (Page 55) shows the map of Bawku Municipality and the selected study communities.

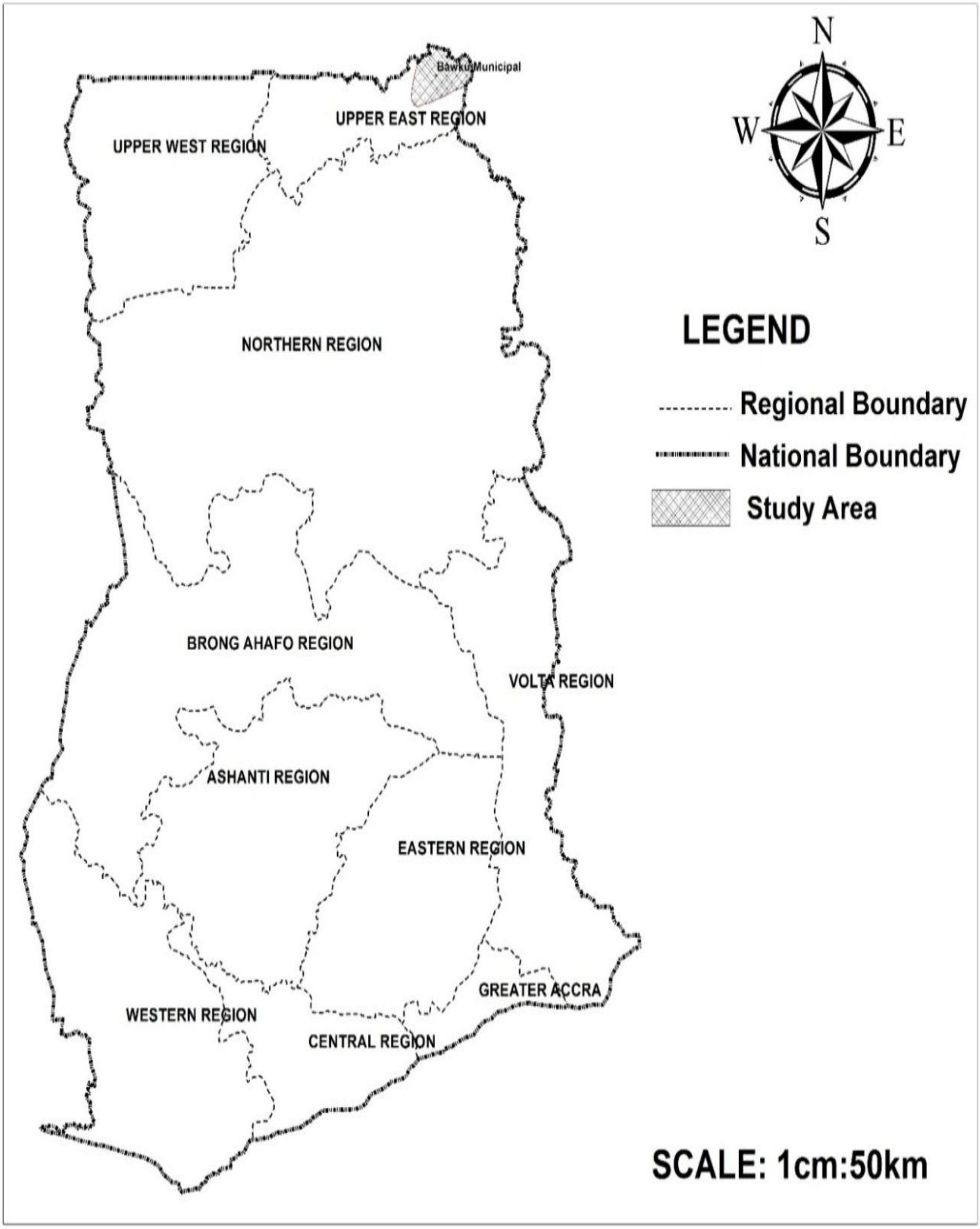


Figure 3.1: Study area in national context

Ghana Statistical Service (2014)

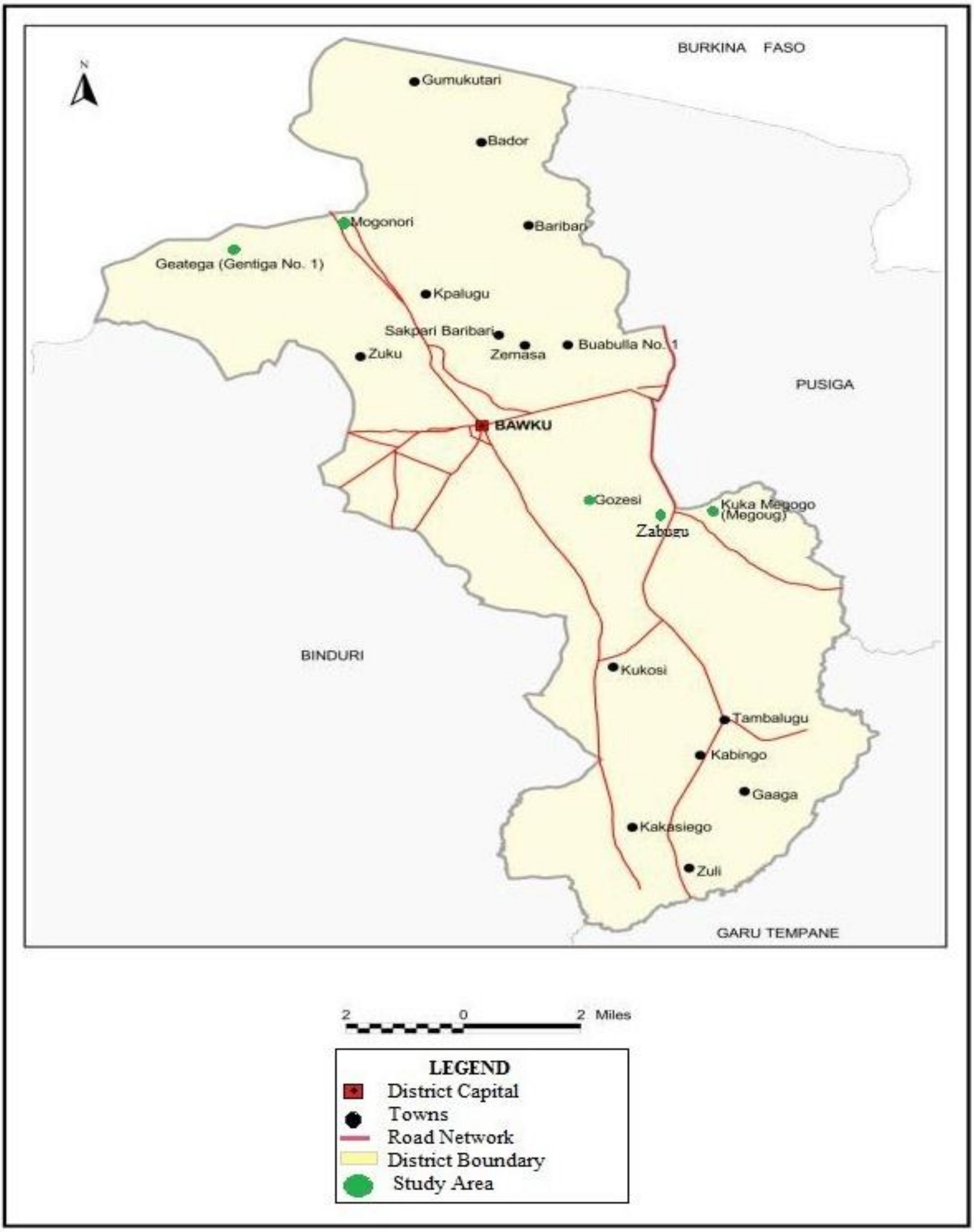


Figure 3.2: Map of Bawku Municipality showing the study communities

Source: Ghana Statistical Service (2014)

The administrative capital is Bawku and it is about 880km (550 miles) from Accra, the national capital (Amikuzuno and Donkoh, 2011). The Municipality has a population of 98, 532 with the males being 47,254 (48.0%) and females 51,284 (52.0%). The urban population is 63.6% whiles the rural population constitutes 36.4% (Ghana Statistical Service, 2014).

Kusasi, Mamprusi, Bissa and Mossi are the main ethnic groups living in the Bawku Municipality (Ghana Statistical Service, 2014). A total of 44.3% of persons in the Municipality have never attended school, 40.2% are currently attending school while 15.4% have attended school in the past. More females, 51.4% compared with males 36.6% have never attended school (Ghana Statistical Service, 2014). The concentration of road networks makes the area easily accessible to traffic and humans. Access to the study area in the course of data collection was therefore not a problem.

3.2.2 Climate and vegetation

The Municipality is under the influence of the tropical continental climate which is characterized by a single rainy season from May to October when the tropical maritime air mass (south west monsoon wind or south westerly winds) influence Ghana (Nikoi, 2010). The mean annual rainfall of the study area is about 1000mm to 1150 mm. A long and severe dry season often follows the rainy season with monthly temperatures varying from 36°C in March to about 27°C in August (Nikoi, 2010).

In the dry season, particularly, between December and February, the dry and dusty harmattan winds (Tropical continental air mass) from the Sahara desert are very intense (Amikuzuno and Donkoh, 2011). The long dry spell promotes the occurrence of bushfires, exposing the soils to erosion by wind and rendering it too impoverished to support plant growth (Yiran *et al.*, 2012). The unstable climatic condition like the long dry season of seven months followed by just a five-month rainy season with recurrent, intermittent droughts and floods in the planting season affect crop yields. Relative humidity in the Municipality is about 35%-65% during the wet season and reduces between 20%-30% (November and April) when the harmattan winds dominate a greater part of Ghana. The study area has small cloud cover which influences the general effect of insolation on moisture leading to the low humidity in the air (Nikoi, 2010).

The vegetation of the Municipality is the Sudan Savanna type which lies to the north of the Guinea Savanna and covers a greater part of Burkina Faso and Mali. The Sudan Savanna vegetation zone is limited to the extreme north-eastern part Ghana in the Upper East Region, covering an area of 2,200 km^2 where the study area is located (Oppong-Anane, 2006 cited in Wood, 2013). The natural vegetation of the Sudan Savanna Zone is characterized by fire-swept short grasses interspersed with low-density woodland of short, low branching, thin-leaved, deciduous species that are drought and fire-resistant. An example of such drought and fire resistant species are the Acacia and Baobab which shed their leaves in the long dry season. These species have long tap and fibrous roots that penetrate the soil to access water. They also have thick barks which help to prevent excessive loss of water during dry seasons. The grass cover of this vegetation belt is sparse and withers in the dry season. However, the grasses become green again with the onset of the rains (Nikoi, 2010). There are some forest reserves, of which most portions have been degraded by man's activities (Oppong-Anane, 2006 cited in Wood, 2013)**.** The important economic trees in the Sudan Savanna belt include baobab, dawadawa, shea tree and Gum Arabic. The main crops cultivated in this vegetation belt include rice, millet, maize, guinea corn, sorghum etc (Nikoi, 2010).

3.2.3 Geology and soil

The topography of the study area is gently rolling with inselbergs (an average height of between 180 and 300 meters above sea level). The soils are laterites and ochrosols weathered from granites and Birimain rocks which form the base rocks (Nikoi, 2010). The lateritic soils are associated with layers of iron stone which covers a few centimeters from the surface. The lateritic soils are not easily permeable and become waterlogged in the rainy season, but dry in the dry season. The lateritic soils are yellowish brown and yellowish grey in colour, silt and sandy loam in texture and poor in organic content (Nikoi, 2010). The ochrosols are also poor in organic matter content, but are loamy, well drained and porous. The low organic matter content of the soils coupled with the continuous disturbance of the soils weakens the soil structure and makes it susceptible to erosion and leaching (Nikoi, 2010). This basically affects soil nutrients needed for plant growth. Climatic elements such as rainfall, temperature and wind influence the soil through weathering. High annual rainfall and temperatures increase the decomposition of the soil. However, the low annual rainfall coupled with high temperature associated with the tropical continental climate of the Sudan Savanna belt result in poor organic matter content, making soil suitability for cropping one of the major problems in crop production (Nikoi, 2010). Thus, low soil organic matter and limited availability of plant nutrients, in particular phosphorus and nitrogen, are major obstacle of crop productivity in the Sudan Savanna (Schlecht *et al.*, 2006).

3.2.4 Economic activities

The economically active population of the Municipality is 70.1%, lower than the regional proportion (73.9%). Of the economically active population, 66.5% are employed and 3.6% are unemployed (Ghana Statistical Service, 2014). According to the Ghana Statistical Service (2014), out of the total of 39,143 inhabitants in various forms of occupations, 46.6% are males while 53.4% are females. The economic activities sustaining the livelihoods of the residents are categorized into agriculture, commerce/ trade and manufacturing/local craft/service.

3.2.4.1 Agricultural activities

The main occupation of the people in the Municipality is agriculture which employs about 65% of the labour force (MoFA, 2010). Out of a total of 15,012 households in the Bawku Municipality, 60.9% are agricultural households (Ghana Statistical Service, 2014). Interestingly, out of the 9,135 households in agriculture, 48.8% live in urban areas compared with 51.2% in the rural areas. Again, it is a fact that more males (47.8%) than females (46.2%) are engaged in agricultural activities (Ghana Statistical Service, 2014). Crop farming alone accounts for almost 90% of all agricultural activities in the Municipality. Farming systems in the Municipality have been modified from shifting cultivation to a combination of compound and bush fallow systems.

Compound cropping involves intensively cropping fields around the compound house with vegetables, millet, guinea corn, maize, cowpea, tobacco, and melons. These fields are kept fertile with household compost and livestock manure. Nonetheless, millet can flourish without inputs and resist low and uneven precipitation. In many ways the millet is ideal for drier areas especially in the Sudan Savanna Zone (Environmental Protection Agency, 2008). The farming system is based on rain-fed cultivation. However, the gradual expansion of irrigation into the Sudan Savanna belt has increased dry-season farming in the Municipality. Tomatoes, onions and rice are the most well-known crops cultivated during the dry season. There are a few dams and dug-out wells which are being used for dry season gardening. Farmers also dig into the sand of dry riverbeds to get water for farming (MoFA, 2010).

Most smallholder farmers use donkeys to plough their land for cultivation since donkeys are substantially cheaper compared to tractors, both in purchase price and maintenance. Livestock, such as cattle, sheep and goats are commonly integrated into the farming systems; a practice known as mixed crop-livestock production (MoFA, 2010). Crop residues from the bush fallow are the main source of livestock feed in the dry season (Bationo and Ntare, 2000). Poultry such as guinea-fowls and chickens are mostly reared in the Municipality. According to Oppong-Anane (2006 cited in Wood, 2013) livestock and poultry production help meet food needs and provide manure for soil nutrients. They may also be used as an important source of income, and serve as the household’s savings bank or insurance in difficult times, especially, guinea-fowl and turkey. This is because urban demand for guinea fowl and turkey are increasing. Therefore, there is the need for the youth to engage in this venture to reduce the unemployment rate in the Municipality. However, small stocks are allowed to forage freely in the dry season and confined in the wet (Oppong-Anane, 2006 cited in Wood, 2013).

Environmental issues, such as soil infertility and degradation, harsh and erratic climatic conditions and pest pressures create challenges to increasing agricultural production (Nikoi, 2010). To add to that, unavailability of advanced agricultural technologies, the limited knowledge on improved agronomic production and management practices among farmers also pose serious danger to the agricultural sector. Finally, inadequate communication and collaboration among MoFA, SARI and the Ministry of Education, has resulted in a significant gap between research, education and extension (EPA, 2008). This gap has created significant obstacles for agricultural development and unimproved livelihoods for smallholder farmers (Nikoi, 2010).

3.2.4.2 Commerce/Trade

Aside agriculture being the main economic activity, the Municipality is notably a vibrant commercial centre, connecting economic activities between other West African states such as Togo, Burkina Faso, Niger and Mali (Acquah, 2011) because of its close proximity to these countries. This provides an important opportunity for the active labour force in the agricultural sector to diversify their livelihood activities to buffer against low crop yield. This has made the Municipality the hub for commercial activities in the Upper East Region. The activities carried out by the players in this sector are mainly wholesale and retail in nature. They cover all kinds of commodities ranging from motorbikes, foodstuff, kolanuts, shea butter, building materials, herbal/ orthodox medicines and clothing. It is interesting to note that in this sector, more females (26.4 %) than the males (16.3 %) are engaged in wholesale and retail (Ghana Statistical Service, 2014).

3.2.4.3 Manufacturing/ local craft industries /services

The positive and significant correlation between local craft industries and economic development can never be over emphasized. Though the local craft industries are underdeveloped, it is fast becoming an important sector in the Municipality. Notable among them are weaving (smock) and pottery. This sector employs a significant number of people and has impacted positively on revenue generation (Ghana Statistical Service, 2010). Almost all these activities derive their raw materials from the local environment (Nikoi, 2010).

Apart from the contribution of the local craft industries, the fast growing pace of the Municipality in recent years after the ethnic clashes in 2007 has attracted other relevant service providers such as banks, credit unions, insurance companies, both orthodox and herbal medicine practitioners, transport, guest houses, private schools and food vendors (chop bars) who have contributed immensely to the economic development of the Municipality especially to the agricultural sector by creating ready markets for the farmers, and sometimes give farmers loans to expand their farming business.

Other groups of service providers in the Municipality are the telecommunication companies, hairdressers, and dressmakers. This has helped augment the economic activities in the Municipality and also contributed tremendously to the creation of productive employment ventures and revenue generation in the Municipality (Ghana Statistical Service, 2014).

According to the Ghana Statistical Service (2014), more females (32.1 %) than males (14.3 %) are employed in the service sector.

3.3 Chapter Summary

The purpose of research is to discover answers to questions through the application of scientific methods. Research methods are therefore the basis upon which a research is founded. This chapter therefore presented the methods and procedures used to conduct the study. The detailed discussions focused on research design and approach, the types and sources of data, the various data collection methods, sampling techniques, data analysis and the description of the study area.

CHAPTER FOUR

INFLUENCE OF OBSERVED CLIMATIC TRENDS ON FOOD CROP PRODUCTION IN THE BAWKU MUNICIPALITY

4.0 Introduction

This chapter presents the results and discussions on the influence of observed climatic trends on food crop production in the Bawku Municipality. The chapter is organised into two major sections. Section one brings out the differences and similarities of farmers' socio-demographic information based on the study communities. Section two presents the results on the influence of observed climatic trends on food crop production. Under this section, the results and discussions on rainfall variations/trends, temperature variations/trends, extreme climatic events, crop yield variation and regression analysis of climate variables on food crop production are presented.

4.1 Socio-demographic information of food crop farmers in the Bawku Municipality

Before understanding the effects of climate variability on food crop production, it is important to have a clear knowledge about the socio-demographic characteristics of respondents. This is because the socio-demographic features of the respondents would throw more light on their vulnerability and the choice of their adaptation strategies to climate variability (Oremo, 2013). From Table 4.1, the majority of the respondents in the sampled communities were male farmers (76.2%) and the remaining 23.8% were females.

Table 4.1: Distribution of respondents by sex and study communities

Sex	Study communities										Total	Percentage
	Mognori		*Zabugu*		*Gozesi*		*Kuka*		*Gentiga*			
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Male	37	17.3	46	21.5	37	17.3	24	11.2	19	8.9	**163**	**76.2**
Female	14	6.5	9	4.2	10	4.8	7	3.3	11	5.1	**51**	**23.8**
Total	**51**	**23.8**	**55**	**25.7**	**47**	**21.9**	**31**	**14.5**	**30**	**14**	**214**	**100**

Source: Field Survey, 2014.

Apusigah (2009) attributes this disparity to household provisioning and production arrangement, tenurial practices and labour appropriations. According to Apusigah (2009), in Northern Ghana, women are considered as non-heirs of household resources including land. This confirms the report by the Ghana Statistical Service (2014) that more males are engaged in agriculture than females in the Bawku Municipality. Traditionally, women's access to land for farming is through men. The gendered nature of this results in male taking control over land administrative structure. This situation perhaps impedes women's access to land for agricultural activities. Across the study communities, the results revealed that out of the 23.8% of female respondents, about 6.5% were from *Mognori* with *Kuka* having the least (3.3%) female respondents. The assumption is that among the study communities, more women in *Mognori* perhaps had access to land than the other study communities.

Table 4.2 presents the distribution of respondents by their age groups. The age group 41- 60 years formed the majority of the respondents (62.6%) with 46.7% males and 15.9% females.

Table 4.2: Distribution of respondents by their age groups

Age Groups	**Study communities**										**Total**	**Percentage**
	Mognori		***Zabugu***		***Gozesi***		***Kuka***		***Gentiga***			
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
25-30years	8	3.7	5	2.3	2	0.9	2	0.9	5	2.3	**21**	**9.8**
31-40years	15	7	14	6.5	12	5.6	10	4.8	8	3.7	**59**	**27.6**
41-50years	19	8.9	20	9.3	19	8.9	16	7.5	14	6.5	**86**	**40.2**
51-60years	9	4.2	16	7.5	14	6.5	6	2.8	3	1.4	**48**	**22.4**
Total	**51**	**23.8**	**55**	**25.7**	**47**	**21.9**	**31**	**14.5**	**30**	**14**	**214**	**100**

Source: Field Survey, 2014.

The indication is that, among the respondents, older people between the ages of 41 and 60 years were engaged in food crop production than those aged between 25 and 40 years. This suggests that majority of the respondents had more years of farming experience. As a result, these farmers were likely to better understand the effects of climate variability on food crop production and might be willing to adopt effective adaptation measures against climate variability (Oremo, 2013). In spite of this, the results show that, the farming population in the study area is ageing out. Therefore, there is the need to encourage more youth into food crop production especially in *Gentiga* and *Kuka* where a small proportion of the respondents interviewed were from the ages of 25 to 40 years. In order to encourage youth involvement in food crop farming, attention should be geared towards factors such as lack of credit, capacity constraints and sustainability of income from farming.

Formal education is regarded as an important factor in the development of agriculture because it improves the capability of farmers to access and conceptualize information significant to constructing innovative ideas and perceive changes that occur in the climate system (Okello and Reddy, 2009; Ochieng, *et al.*, 2012; Gbegeh and Akubuilo, 2012; cited in Oremo, 2013). It therefore becomes pertinent for the study to know the level of formal education of respondents (Table 4.3). From Table 4.3, the majority of the respondents (80.8 %) had never been to school, 13.6% had primary education and 4.7% had secondary education whereas none of the respondents had tertiary education.

Table 4.3: Distribution of respondents by level of education.

Study communities	**Level of Formal Education**								**Total**
	Primary School		**Middle School**		**Secondary School**		**Never been to School**		
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Mognori	7	3.3	0	0	4	1.9	40	18.7	51
Zabugu	4	1.9	1	0.5	2	0.9	48	22.4	55
Gozesi	10	4.8	0	0	2	0.9	35	16.4	47
Kuka	6	2.8	1	0.5	2	0.9	22	10.3	31
Gentiga	2	0.9	0	0	0	0	28	13.1	30
Total	**29**	**13.6**	**2**	**0.9**	**10**	**4.7**	**173**	**80.8**	**214**

Source: Field Survey, 2014.

This signifies low level of formal education among farmers in the study area. Low level of formal education among farmers is likely to hamper the adoption of agricultural technologies (Oremo, 2013). Across the study communities, only two respondents from *Gentiga* had primary education, the rest of the respondents had never been to school. This may be partly due to the absence of a school in *Gentiga*. The high proportion of farmers who had been to school were from *Gozesi* and *Mognori*. The level of education in *Zabugu* and *Kuka* were similar.

Table 4.4 reveals that the level of formal education varies among age groups. For instance, about 126 respondents representing 58.9% who had never been to school were in the age range of 41-60, while the majority of the respondents who had been to school were within the 25-40 age group. Oremo (2013) argues that younger farmers tend to have better formal education and are likely to be more versatile to innovation than older farmers.

Table 4.4: Distribution of respondents by their age group and level of education.

Age Group	**Level of Formal Education**								**Total**
	Primary School		**Middle School**		**Secondary School**		**Never been to School**		
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
25-30 years	11	5.1	0	0	4	1.9	6	2.8	21
31-40 years	10	4.7	0	0	6	2.8	41	19.2	59
41-50 years	8	3.7	2	0.9	0	0	78	36.4	86
51-60 years	0	0	0	0	0	0	48	22.4	48
Total	**29**	**13.6**	**2**	**0.9**	**10**	**4.7**	**173**	**80.8**	**214**

Source: Field Survey, 2014.

With regards to farm size, the majority (50.9%) of the respondents had farm sizes of between 4-6 acres of land, while 3.7% had between 7-9 acres of land. Only a small proportion (2.4. %) of farmers cultivated on 10-25 acres of land (Table 4.5; page, 67). This was the situation in all the study communities where majority of the respondents had farm sizes between 4-6 acres. Generally, the results therefore support the report by the MoFA (2010) that majority of farmers in the Upper East Region have farm sizes not more than 10 acres. The main food crops grown by the respondents include maize, millet, vegetables, rice, cowpea, groundnuts, watermelon, soybean, sweet potatoes and sorghum.

Table 4.5: Distribution of respondents by the study communities and their farm size

Study Communities	**Farm size**												**Total**
	1-3 acres		**4-6 acres**		**7-9 acres**		**10-15 acres**		**16-20 acres**		**21-25 acres**		
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Mognori	16	7.5	31	14.5	2	0.9	0	0	1	0.5	1	0.5	**5**
Zabugu	28	13.1	24	11.2	3	1.4	0	0	0	0	0	0	**58**
Gozesi	18	8.4	26	12.1	1	0.5	1	0.5	1	0.5	0	0	**54**
Kuka	13	6.1	17	7.9	1	0.5	0	0	0	0	0	0	**44**
Gentiga	17	7.9	11	5.1	1	0.5	1	0.5	0	0	0	0	**35**
Total	**92**	**43**	**109**	**50.9**	**8**	**3.7**	**2**	**0.9**	**2**	**0.9**	**1**	**0.5**	**214**

Source: Field Survey, 2014

The distribution of respondents by their monthly income level (Table 4.6) showed that 2.3% of the sampled households had a monthly income below Gh₵ 20, 52.3%, had between Gh₵ 20 and Gh₵ 60, while 22.9% had between Gh₵ 100 and GH₵ 300. Only 1.9% had a monthly income that was above Gh₵ 300; these respondents were from *Zabugu* and *Gozesi* (Table 4.6; page, 68). Clearly, as noted from Table 4.6, none of the respondents from *Gozesi* and *Gentiga* had monthly income above Gh₵ 300. None of the respondent from *Kuka* had monthly income below Gh₵ 20. Comparing the monthly income of the respondents to the monthly minimum wage rate in Ghana (Gh₵ 180) (Ghana Statistical Service, 2014), it is obvious that the majority (71%) of the respondents earned below the monthly minimum wage. This could have profound negative implication on food crop production because income below the monthly minimum wage may threaten farmers' ability to purchase farm inputs and pay for operational cost.

This would worsen in situations where farm inputs are imported due to the depreciation of the cedi against the US dollar (GhC 1 = USD 3.215). Thus, prices of imported farm inputs on the market would possibly increase appreciably due falling value of the cedis.

Table 4.6: Distribution of respondents by the study communities and their income per month

Income per month	**Income per month**										**Total**	**Percentage**
	Mognori		***Zabugu***		***Gozesi***		***Kuka***		***Gentiga***			
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Below Gh C20	1	0.5	2	0.9	1	0	0	0	1	0.5	**5**	**2.3**
GhC 20-40	13	6.1	10	4.8	11	5.1	9	4.2	15	7	**58**	**27.1**
GhC 40-60	12	5.6	17	7.9	10	4.8	5	2.3	9	4.2	**54**	**25.2**
GhC 60-100	9	4.2	18	8.4	13	6.1	3	1.4	1	0.5	**44**	**20.6**
GhC100- 200	9	4.2	6	2.8	10	4.8	7	3.3	3	1.4	**35**	**16.4**
GhC 200-300	6	2.8	1	0.5	2	0.9	4	1.9	1	0.5	**14**	**6.5**
Above GhC 300	1	0.5	2	0.9	0	0	1	0.5	0	0	**4**	**1.9**
Total	**51**	**23.8**	**55**	**25.7**	**47**	**21.9**	**31**	**14.5**	**30**	**14**	**214**	**100**

Source: Field Survey, 2014

From the survey, farm size had no direct correlation with the monthly income of farmers (Table 4.7). For instance, the majority of the farmers who had farm sizes of between 1-3 acres had a monthly income between GhC 20 and GHC 300 while farmers who had farm sizes of between 7-9 acres also had a monthly income between GhC 40 and GhC 300 (Table 4.7; page, 69). This suggests that the farm size does not solely determine the level of income of farmers. Within this general picture, there may be other off-farm jobs or non-farm businesses owned by farmers that generate income for them. This possibly explains the variations in monthly income across the study communities.

Table 4.7: The relationship between respondents' income per month and their farm size

Income per month	Farm size												Total	Percentage
	1-3 acres		4-6 acres		7-9 acres		10-15 acres		16-20 acres		21-25 acres			
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%		
Below Gh ₵20	5	2.3	0	0	0	0	0	0	0	0	0	0	**5**	**2.3**
Gh₵ 20-40	38	17.8	20	9.3	0	0	0	0	0	0	0	0	**58**	**27.1**
Gh₵ 40-60	25	11.7	28	13	1	0.5	0	0	0	0	0	0	**54**	**25.2**
Gh₵ 60-100	15	7	26	12.1	2	0.9	0	0	1	0.5	0	0	**44**	**20.6**
Gh₵100- 200	8	3.7	22	10.3	3	1.4	2	0.9	0	0	0	0	**35**	**16.4**
Gh₵ 200-300	1	0.5	11	5.1	1	0.5	0	0	1	0.5	0	0	**14**	**6.5**
Above Gh₵ 300	0	0	2	0.9	1	0.5	0	0	0	0	1	0.5	**4**	**1.9**
Total	**92**	**43**	**109**	**50.9**	**8**	**3.7**	**2**	**0.9**	**2**	**0.9**	**1**	**0.5**	**214**	**100**

Source: Field Survey, 2014

From the results presented on the socio-demographic characteristics of the respondents, it may be assumed that most respondents especially respondents from *Gentiga* were the most vulnerable to the effects of climate variability and extreme climatic events. This is because most of the respondents had low income, small farm size and had never been to school. These characteristics according to Oremo (2013) limit the application of adaptation strategies.

4.2 Influence of Observed Climatic Trends on Food Crop Production

This section analyses the influence of observed climatic trends on food crop production which provides a basis for understanding the effects of climate variability on food crop production. Under this section, the results and discussions on rainfall and temperature variation, crop yield variation and regression analysis of climate variables on food crop production are presented.

4.2.1 Rainfall variation/trend

Rainfall amount and timing influenced the yield of crops. Low rainfall amounts can be detrimental to crop yield, especially if dry periods occur during critical development stages (Fosu-Mensah, 2012). The total annual amount of rainfall and the trend over the last 15 years in the Bawku Municipality are shown in Figure 4.1. The mean annual total rainfall from 1999-2013 is 901.9mm.

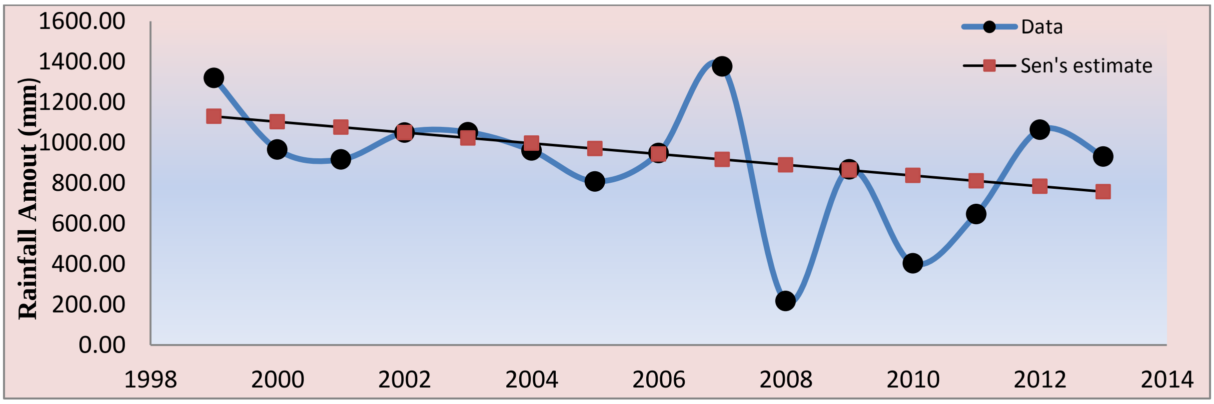


Figure 4.1: Total annual rainfall trend in the Bawku Municipality in the past 15 years
Source: Author's Plot from Bawku Weather Station, 2014.

The rainfall data shows that the Municipality received less than 1400 mm of annual rainfall for the 15 year period with an annual average of between 114.7mm and 18.1mm. The total annual rainfall for the period ranged from a low of 217.9mm in 2008 to a high of 1375. 97mm in 2007. The years 1999 and 2000 showed a decreased trend per year. However, the rainfall amount increased marginally to 1051.5 mm in 2003, and continued to fluctuate until

2007 when the amount of rainfall increased significantly from 948.1mm in 2006 to 1375.97mm in 2007. There was a sharp decrease after 2007 and continued to fluctuate till 2013 (Figure 4.1). Generally, the Mann-Kendall trend test of the rainfall dataset from1999 to 2013 shows that the trend is not statistically significant even at 10% significance level (See appendix III B). The Sen's estimate (slope) in Figure 4.1 (Page, 70) indicates a decreasing trend. This is congruent to the findings of Asante and Amuakwa-Mensah (2015) whose study of climate change and variability in Ghana showed decreasing trends of rainfall variability. The variability in the year to year rainfall particularly towards the decreasing trend is a cautioning sign to the farming communities in the Municipality as this may adversely affect their livelihoods.

Figure 4.2: Annual rainfall deviations in the Bawku Municipality in the past 15 years
Source: Author's Plot from Bawku Weather Station, 2014.

From Figure 4.2, the years 2005, 2008, 2010 and 2011 had a negative deviation signifying meteorological drought (period of below average precipitation) periods with the worst drought occurring in 2008. Global record of rainfall indicates a substantially high rainfall in 2005 and 2010 resulting in severe floods in many parts of the world (NASA, 2011). The years 1999, 2000, 2001, 2002, 2003, 2004, 2006 and 2007 had a positive deviation with 1999 and 2007 recording the highest values. The positive deviation in 1999 and 2007 according to Paeth *et al.*, (2011) is attributed to the ENSO effects which caused much rain to fall in Sub Sahara Africa. This implies that severe floods might have occurred in 1999 and 2007 in the

Bawku Municpality. This confirms the report by Daily Graphic online (2015) that floods occurred in the Upper West Upper East and the Northern Regions of Ghana. The outlier that occurred in This may have affected agricultural activities in the Municipality because according to Falloon and Betts (2009 cited in Gornall *et al*., 2010), the effects of flooding is becoming severe to the extent that, agricultural machinery may simply not be adapted to wet conditions. This indirectly delays farming operations and consequently affect crop yield. The estimated annual anomaly of rainfall (Figure 4.2; page, 71) and the coefficient of variation (0.3343) in Table 4.8 indicate that the total amount of annual rainfall varied substantially from year to year. This confirms the prevailing evidence that rainfall in the semi-arid regions of Africa is highly variable (Amikuzuno and Donkoh, 2012).

Table 4.8: Summary statistics of climate variables and major food crop production

Variables	**Mean**	**Standard Deviation**	**Coefficient of Variation**
Rainfall	901.92	301.50	0.33429
Temperature	28.89	0.45	0.01545
Maize	24880.38	11440.62	0.4598
Millet	22172.45	12533.54	0.5653
Rice	20979.07	8097.14	0.3860

Source: Author's computation based on annual data obtained from MoFA and BWS, 2015

With regard to farmers' observations, all the respondents were of the view that they had observed rainfall variation in the past 15 years. Approximately, 37% of farmers were of the opinion that the amount of rainfall has reduced. A significant percentage of these respondents were between the ages of 31-60 years. Thirty five of the respondents representing 16.4% reported a reduction in the length of rainy season with majority of these respondents aged between 31-50 years. From the survey, majority of the respondents between the ages of 25 and 30 years, seem to have different views on the above manifestations of rainfall variability (Table 4.9; page, 73). For example, only 4 respondents (1.9%) and 2 respondents (0.9%) out of the total of 21 respondents (9.8%) within the ages of 25 and 30 years cited reduction in the amount of rainfall and reduction in the length of the rainy season as manifestations of rainfall variability respectively.

Table 4.9: Respondents' observation of the manifestations of rainfall variation

Age groups	Reduction in the amount of rainfall		Reduction in the length of rainy season		Irregularities in the amount of rainfall		Irregularities in the length of rainy season		Total	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	%
25-30 years	4	1.9	2	0.9	9	4.2	6	2.8	21	9.8
31-40 years	23	10.7	10	4.7	15	7	11	5.1	59	27.6
41-50 years	32	14.9	18	8.4	22	10.3	14	6.5	86	40.2
50-60 years	20	9.3	5	2.3	15	7	8	3.7	48	22.4
Total	**79**	**36.9**	**35**	**16.4**	**61**	**28.5**	**39**	**18.2**	**214**	**100**

Source: Survey Field, 2014.

About 28.5% and 18.2% noticed an irregularity in the amount of rainfall and a reduction in the length of rainy season respectively (Table 4.9). Specifically, across the age groups, majority of the respondents between the ages of 25-30 years had observed irregularities in the amount of rainfall. The variations within the age groups as observed from the results may be due to their years of experience. For instance, as a consequence of more years of experience, it is obvious, as anticipated; respondents within the ages of 31-60 years may have noticed a reduction in the amount of rainfall than respondents between the ages of 25-30 years.

Similarly, key informants from SARI, MoFA and GMA had also noted pronounced variation in the rainfall pattern. According to the key informants, the rains either come earlier or later than expected. This was supported by a male farmer in *Gentiga* who pointed out in a focus group discussion that:

> *"...when we were young, our wells and rivers were full in the rainy season which enabled us to get water in the dry season, drawing water from wells was not difficult but nowadays our wells and rivers have little water even in the rainy season... The rains do not fall as they used to. My biggest worry is its unpredictable nature"* (Focus group discussion, 2014).

Generally, it was observed that respondents were much perturbed by the abnormality of the rainfall pattern in the Municipality which sometimes made it difficult to accurately predict when to start planting. The results presented show farmers observations are in line with the historical rainfall data for the 15 year period.

4.2.2 Mean annual maximum and minimum temperature variation and trend

Figure 4.3 presents the mean annual variation/trend in minimum temperature in the Bawku Municipality. The mean annual minimum temperature from 1999 to 2013 fluctuated between 21.2°C and 23.4°C with a mean value of 22.7°C. The Sen's estimate of the Mann-Kendall test shows that there is a significant decreasing trend in the mean annual minimum temperature (Figure 4.3) for the 15 year period (1999 to 2013). However, the Mann-Kendall trend statistics for mean annual minimum temperature is not statistically significant even at 10% significance level (See appendix III).

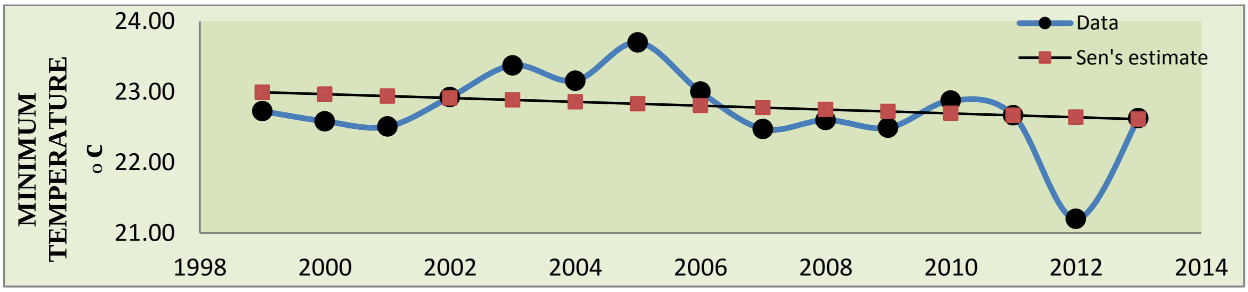


Figure 4.3: Mean annual trend in minimum temperature in the Bawku Municipality

Source: Author's Plot from Bawku Weather Station, 2014.

Despite the decreasing trend, the mean annual deviation in minimum temperature shows quite substantial fluctuations (Figure 4.4; Page, 75). The mean temperature for 1999 (22.7°C) was found to be the same as the mean value (22.7°C) for the 15 year period, showing no change for 1999. However, the years 2002 to 2006 and 2010 showed a significant increase in minimum temperature with a positive deviation of between 0.2°C and 0.9°C above the baseline average. The rest of the years recorded negative deviation with the highest decrease of 1.53°C observed in 2012. This significant inter annual variation in minimum temperature may have affected crop production in the Municipality. This is because a decrease in minimum temperatures affects night time plant respiration rate and possibly reduces crop yield (Hatfield *et al.*, 2011), while the exposure of plants to higher minimum temperatures decrease the ability of plants to grow and also reduce crop yield (Welch *et al.*, 2010).

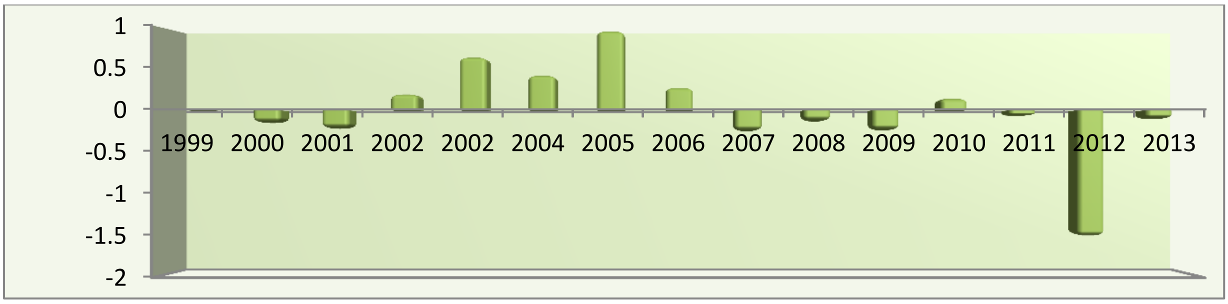


Figure 4.4: Mean annual deviation in minimum temperature in the Bawku Municipality
Source: Author's Plot from Bawku Weather Station, 2014.

The mean annual maximum temperature varied between 33.6°C and 35.8°C for the 15 year period. The total mean maximum temperature from 1999-2013 was 35.05°C. The trend statistics of the Mann-Kendall test for mean annual maximum temperature is not statistically significant at 10% significance level (See appendix III B). However, the observed trend of the Sen's estimate of the Mann-Kendall test for the mean annual maximum temperature over the 15 year period shows a decreasing trend (Figure 4.5).

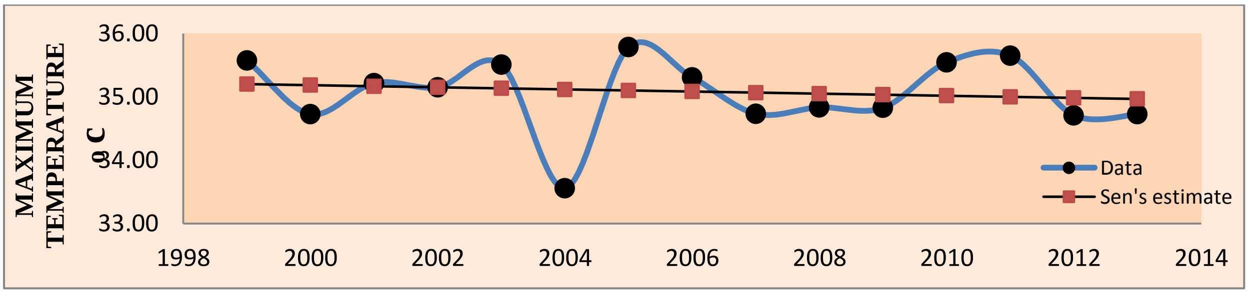


Figure 4.5: Mean annual trend in maximum temperature in the Bawku Municipality
Source: Author's Plot from Bawku Weather Station, 2014.

Notwithstanding, the mean maximum temperatures from 1999 to 2013 showed distinctive inter annual variation (Figure 4.5). In general, maximum temperature decreased below the mean for the years 2000, 2004, 2007, 2008, 2009, 2012 and 2013; indicating that these years were relatively cooler. The highest decrease occurred in 2004 with a decrease of 1.6°C below the baseline average. This confirms the report by Asante and Amuakwa-Mensah (2015) that very cold winds were experienced in 2004. On the other hand, the year 2005 was marked as the warmest year with a positive deviation of 0.8°C, which was higher than the global record of 0.62°C. The other warmest years include, 2010, 1999, 2003 and 2011. These confirm the findings of NASA (2011) that 2005 and 2010 were the warmest years on record since 1880. In addition, the mean annual deviation (Figure 4.6) shows more warm years than cold years for the 15 year period. This has the tendency to cause variation in crop production in the Municipality.

Though, there are significant variations in the inter-annual minimum and maximum temperature in the Municipality, the coefficient of variation (0.0155) for the mean annual temperature shows slight variation (Table 4.8; page, 73). This confirms the findings of Amikuzuno and Donkoh (2012) that Northern Ghana has not significantly experienced notable temperature variation.

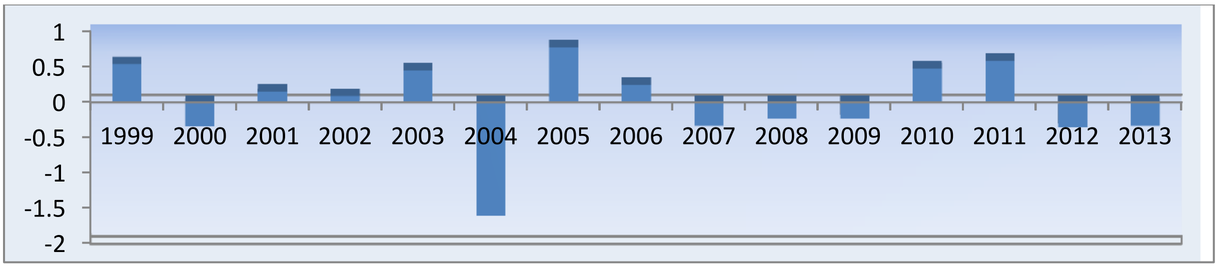


Figure 4.6: Mean annual deviation in maximum temperature in the Bawku Municipality
Source: Author's Plot from Bawku Weather Station, 2014.

Superimposing the annual mean maximum temperature to the annual rainfall deviation for the 15 year period shows that effective rainfall for food crop production in 2005, 2010 and 2011 was very low. This is because annual rainfall for these years were below the baseline average while temperature was high. Low annual rainfall coupled with high temperature on one hand, result in poor organic matter content, making soil suitability for cropping one of the major problems in crop production (Nikoi, 2010). This is likely to have negative consequences on food crop production. On the other hand, the high rainfall coupled with low maximum temperature in 2007 and 2012 suggests that effective rainfall for these years were high. This may have benefited some crops. The years 1999 and 2003 recorded high temperature and high rainfall. The implication of high temperature and high rainfall according to Shakoor *et al.* (2015) is beneficial for all tropical crops but will produce negative effects if these climatic variables are increased too much in the future.

With respect to respondents' observations, the results indicate that most farmers (86.4%) had observed temperature variation in the last 15 years. Majority of the farmers (76.1%) who observed temperature variation believed that temperature has been increasing for the past 15 years (Figure 4.7) whereas 10.3% observed irregularities in temperature.

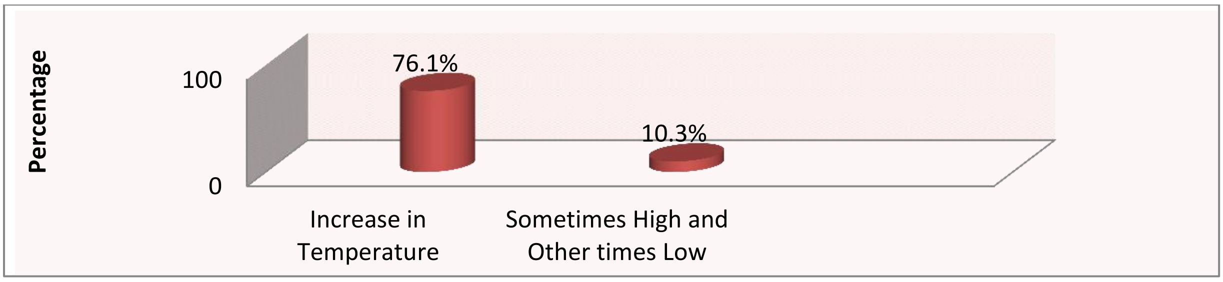


Figure 4.7: Respondents' observations of the manifestations of temperature variation
Source: Field Survey, 2014.

Though, most farmers asserted that there has been an increase in temperature, the observed mean annual temperature for the Municipality showed a decreasing trend. Farmers' observations are therefore at variance with the observed trend. Perhaps, the daily and monthly temperatures observed by the farmers are significant enough for them to notice some increase in temperature. From the results, it is clear that farmers are aware of temperature variation of the Municipality through their own experiences of the past.

4.2.3 Extreme Climatic Events

Over a span of few decades, extreme meteorological events have led to the destruction of plantations and infrastructure, and an increase in the degradation of farmland and more especially, have seriously disrupted the crop production system of smallholder farmers around the world (Tesso *et al.*, 2012). These signs according to the FAO (2008) framework are attributed to climate change and variability. All of the respondents had observed an extreme climatic event over the past 15 years. Fifty-six percent detected drought as most prominent manifestation of extreme event, while 35.3% and 8.9% noticed strong winds and floods as other manifestations of extreme climatic event in the Municipality respectively (Figure 4.8).

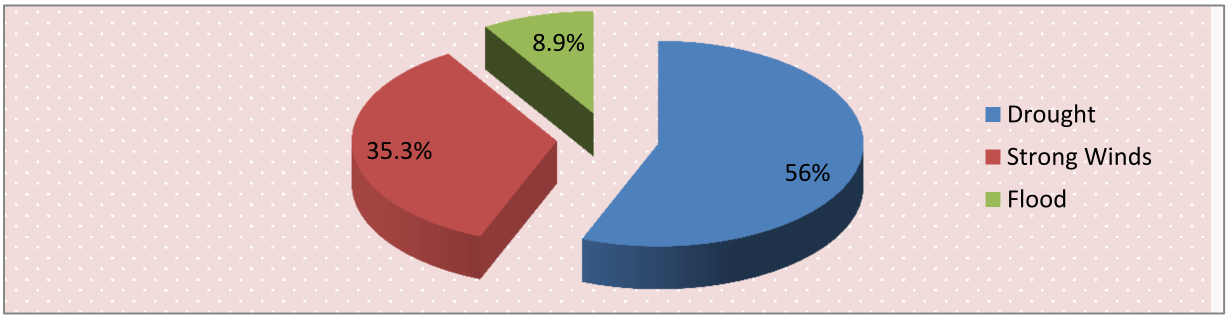


Figure 4.8: Respondents' observations of the manifestation of extreme climatic events
Source: Field Survey, 2014

Table 4.10 (Page 79) presents years of extreme climatic events by meteorological data as against farmers' observations in the study communities. The years 2008, 2009, 2010 and 2011, were cited by the farmers as the years they experienced droughts with 2010 cited by most farmers in all the five communities as the year of worst drought apart from the 1983/1984 dry spell. However, the meteorological data shows that 2005, 2008, 2010 and 2011 were the years of drought with 2008 as the worst drought.

Table 4.10: Years of extreme climatic events by study communities and meteorological data

Extreme climatic events	Study Communities					Meteorological data indicating years of events
	Mognori	***Zabugu***	**Gozesi**	***Kuka***	***Gentiga***	
Drought	2010, 2009	2010, 2011	2010	2010	2010, 2011	2005, 2008, 2010, 2011
Floods	2007, 2011, 2012	2007	2007	2007	2007	1999, 2007 and 2012
Strong winds	2011, 2012 2013,	2009, 2012, 2013	2010, 2013	2012, 2013	2011, 2012, 2013	2001 2002 2005 2007, 2010, 2011

Source: Field Survey, 2014

Across the five communities, farmers noted 2007 as the year of worst flood that inundated several farm lands in the Municipality. The meteorological record on the other hand, shows that floods occurred in 1999, 2007 and 2012. According to an official of the GMA at Bawku, the flood of 2012 was not severe; communities in the low lying areas and near river banks were mostly affected. Given the location of *Mognori* near a tributary of the White Volta, it is not a surprise that farmers in *Mognori* stated that they experienced floods in 2012. Strong winds were experienced by farmers in 2010, 2011 and 2012 while meteorological records indicate that strong winds were severe in 2001, 2002, 2005, 2007, 2010 and 2011.

The cross examination of years of extreme climatic events show some consistencies among the selected communities and the meteorological data. For instance, meteorological data and farmers observations' show that drought and flood occurred in 2010 and 2007 respectively. However, some disparities exist between farmers' observations and the meteorological data on extreme climatic events. For example, farmers did not cite 2005 and 2008 as years of drought but meteorological data indicates 2005 and 2008 as drought years. The disparities between farmers' observations and meteorological records may be due to farmers' inability to accurately recall past and intermediate years of extreme climatic events. This is because from the results, it seems that farmers recall recent and unique events related to extreme climatic conditions than long term climatic events.

Furthermore, focus group discussions held in the five communities brought to light the fact that droughts and strong winds were not new phenomena. What is new is their increased frequency in recent times. A farmer at *Kuka* describes drought as an evil event which attacks unexpectedly. In her own words:

> *"Drought is like an evil person who attacks, frustrates and drains you till you cannot do anything. It comes to destroy everything, no water to drink since rivers, streams and wells dry up…"* (Focus group discussion, 2014)

The observations of the farmers and key informants on extreme events are that, the Municipality is getting drier due to pronounced droughts. This outcome reflects the findings of Schmidhuber and Tubiello (2007 cited in Chijioke *et al.,* 2011) and the Climate Change and Food Security Framework (CCFSF) developed by the FAO (2008) which states that, extreme events are anticipated to increase in occurrence. According to the framework, the expected increases in mean temperatures and precipitation will not manifest through constant gradual changes, but will instead be experienced as increased frequency; duration and intensity of hot spells and precipitation events. The frequency and intensity of the extreme climatic events according to the conceptual framework for the study in section 2.7 of chapter two can make the livelihoods of food crop farmers more vulnerable at certain times of the year. Drawing from the responses, it can be concluded that, farmers in the Municipality are exposed to climate variability and extreme climatic events. The exposure of farmers relates to the changes in climate variability, magnitude and frequency of extreme climatic events which according to O'Brien *et al*. (2004) is one of the determinants of farmers' vulnerability to climate variability. Hence, farmers in the Municipality are highly vulnerable to climate variability, particularly to rainfall variations and unexpected shocks from extreme climatic events such as strong winds, flood and drought which are beyond the scope of the farmers to control. Spatially, since respondents were within the same agro ecological zone (Sudan Savanna), it was assumed that respondents were exposed to the same level of climate anomaly especially drought (Eakin and Bojorquez-Tapia, 2008 cited in Antwi-Agyei *et al.*, 2012). Hence, their vulnerability in terms of drought exposure were similar across the study communities. However, respondents at *Mognori* were highly vulnerable to flood due to their location near a tributary of the White Volta.

The results, as presented, partly answer the research question on how vulnerable are food crop farmers to climate variability and partly validates the second objective which sought to assess the vulnerability of food crop farmers to climate variability.

4.2.4 Variation in crop production

Figure 4.9 shows variation in the output figures of the three major food crops grown in the Municipality from 1999 to 2013. The first five years of the study period depict high production for the major food crops as compared to the second five years of the study period. Even though production was high for the first five years, there was a significant variation in the major food crop production.

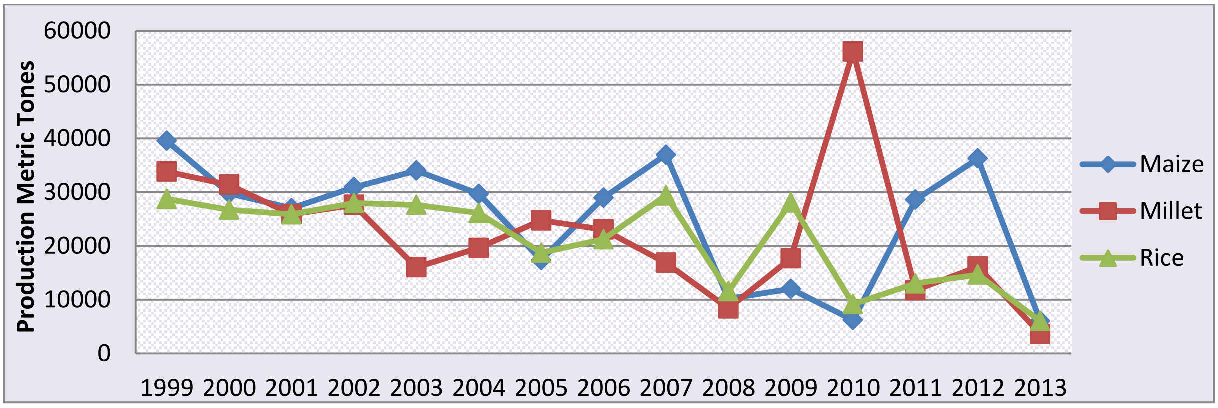


Figure 4.9: Major food crop production in the Bawku Municipality
Source: Author's plot from MoFA Data.

The low level of production in 2013, according to the Director of MoFA, was as a result of the carving out of a new district (Binduri District) from the Municipality. He explained that the splitting of the Bawku Municipality has reduced the production level of food crop since most food crop farmers are now part of the Binduri District. However, the year 2010 marked the worst season for maize and rice farmers when output levels fell tremendously. This is most likely due to the high maximum temperature and low amount of rainfall recorded in 2010. Boote and Sinclair (2006), Tunde *et al.* (2011) and Fosu-Mensah (2012) have argued that high temperature and low rainfall are the key constraints to maize and rice production.

Notwithstanding the above information, the output of millet increased in 2010. Given that millet is drought tolerant and grown as a famine crop (Tunde *et al.*, 2011 and Fosu-Meansah, 2012); most farmers may have shifted to the cultivation of millet when rainfall was expected to be below average in 2010. This reflects the assertion by a key informant from SARI that, millet production has almost replaced maize due to short and erratic rainfall. This may have contributed to the increased millet production in 2010.

In general, the coefficient of variation in Table 4.8 shows significant variation in maize (CV=0.4598), millet (CV=0.5653) rice (CV=0.3860) for the 15 year period. This supports the assertion by the Director of MoFA in the Municipality that, crop production is highly variable and yields are very low compared to other parts of the country. The implication is that food security and farmers' livelihood would be adversely affected (Conceptual framework, section 2.7 of chapter two). In view of the rainfall data from 1999-2013, it appears that as rainfall amount increases, invariably production levels for maize and rice also increase.

4.2.5 Analysis of climate variables on food crop production

Multiple regression analysis is a major statistical technique for investigating and modelling climate variables and crop production. Multiple regression assumes that variables have normal distributions, and require homoscedasticity (variance of errors is the same across all levels) and serially uncorrelated errors (variables in the regression are responding independently) in order to establish validity (Balance, 2011). Non-normally distributed variables can distort relationships and significance of tests. When the variance of errors differ at different values, heteroscedasticity is indicated. The presence of heteroscedasticity can lead to weak analysis and seriously falsify the results of the regression. Similarly, the presence of serial correlation of errors (autocorrelation) can underestimate standard errors and label variables as statistically significant when they are not (Balance, 2011). On the basis of these, it is important to conduct residual diagnostic test (test for model adequacy) to assess whether the parameters of the estimated regression equation satisfy the assumptions of the regression model. This section therefore presents the results for normal distribution, heteroscedasticity and serial correlation, and the regression results for climate variability on food crop production in the Bawku Municipality. The results are presented for the major food crops (maize, millet and rice) produced in the Municipality.

4.2.5.1 Regression results for rice production

The results of the residual diagnostic test (a test to assess whether the parameters of the estimated regression equation are problem free) for rice production are presented in Table 4.11. The residual diagnosis for the test for heteroscedasticity for rice using the Breusch-Pagan-Godfrey test shows that there is no heteroscedasticity at 5% significance level, thus; the variance of error term is constant.

Table 4.11: Diagnostic test statistics for rice production

Diagnosis	**Test-Statistics**	**Probability**
Heteroscedasticity	3.311844	0.3460
Autocorrelation	0.616413	0.4324
Normality	3. 3790	0.1846

Source: E-Views Estimation by author, 2015

The result of the serial correlation in determining the autocorrelation shows that there is no correlation among the residuals in the regression model for rice. The test for normality using a Jarque-Bera statistics indicates that the residuals are normally distributed. The results of the diagnostic test for rice production therefore satisfied the assumptions of the multiple regression model. This implies that there are no problems that will significantly affect the regression results for rice production.

The results of the log-linear regression model used for estimating the influence of climatic variables (mean annual temperature and annual rainfall) and soil pH (the measure of acidity or alkalinity in the soil) as a proxy for soil fertility on rice production is presented in Table 4.12

Table 4.12: Regression statistics for rice production

Variable	Coefficient	Standard Error	T-Statistics	Probability
Constant	-7.619448	21.26389	21.26389	0.7269
LnaverageTemp	1.077336	1.077336	0.170053	0.8681
LnRainfall	0.323560	0.232461	1.391894	0.1915
Lnsoil-Ph	6.644933	2.564687	2.590934	0.0251*

R Squared =0.5838; Adjusted R Squared=0.4704 and F-Statistics = 5.1452 ($p< .0182$)
*. *Regression is significant at the 0.05 level.* Source: E-Views Estimation by author, 2015

The coefficient of determination (R^2= 0.5838) of the results shows that about 58.4% of the variation in the log of rice is explained by the log of average temperature, annual rainfall and soil fertility. The remaining percentage (47.3%) could be attributed to other factors such as seed varieties, method of cultivation etc. Average temperature and annual rainfall are not statistically significant even at 10% significance level. This may be attributed to less variation in average temperature (Coefficient of variation= 0.0155) during the study period (1999-2013) and supplemental irrigation for rice production in the Sudan Savanna Zone (Acquah, 2011 and EPA, 2008). The results further indicate that soil pH is statistically significant at 5% ($p< .0251$) and positively influences rice production. This may be due to the desirable soil pH (5.5 to 6.5) for rice production in the Bawku Municipality (see appendix III A). The result therefore implies that a 1% increase in soil pH, holding other variables constant leads to a 6.6% increase in rice production and output. The estimation therefore shows that rice production in the Municipality for the 15 year period was largely dependent on soil pH. This result is similar to the findings of Azman *et al.* (2014) who observed in their study that, relative rice yield is affected by soil pH. According to them, as the soil pH increases to the desirable amount, the relative rice yield also increases. This may suggest that growing rice in an area with low soil pH could have adverse effects on rice production. From the regression results, it could be ascertained that rainfall and temperature were not significant in explaining factors for variation in rice production in the Municipality from 1999 to 2013.

4.2.5.2 Regression results of maize production

The result of the Breusch-Pagan-Godfrey test is not statistically significant at 10% which shows that there is no heteroscedasticity (Table 4.13). This implies that the variance of error term is constant.

Table 4.13: Diagnostic test statistics for maize production

Diagnosis	Test-Statistics	Probability
Heteroscedasticity	0.4810	0.2140
Autocorrelation	0.0869	0.7682
Normality	0.9865	0.6106

Source: E-Views Estimation by author, 2015

The diagnostic result for autocorrelation among residuals shows that there is no autocorrelation among the residuals regression model for maize production. The normality test of residuals also indicates that the residuals are normally distributed. The results presented in Table 4.13 therefore signify that the regression model is devoid of serious problems that may affect the findings for maize production.

Table 4.14 (Page, 86) presents the results of the multiple regression used for estimating the influence of annual rainfall, average temperature and soil organic matter (proxy for soil fertility) on maize production. From the results, the F- statistic is statistically significant at 5% level ($p < .0131$). This means that the explanatory variables specified in the maize production model are jointly significant.

Table 4.14: Regression statistics for maize production

Variable	Coefficient	Standard Error	T-Statistics	Probability
Constant	27.67440	28.20512	0.981184	0.3476
LnaverageTemp	-3.913351	8.010983	-0.488498	0.6348
LnRainfall	0.668053	0.271932	2.456692	0.0319*
LnOrganicmatter	1.872949	0.777664	2.408429	0.0347*

R Squared= 0.6091; Adjusted R Squared=0.5025 and F-Statistics=5.7141 (p< .0131)

*. *Regression is significant at the 0.05 level*. Source: E-Views Estimation by author, 2015

In other words, annual rainfall, average temperature and organic matter are jointly significant. The results from Table 4.14 show that about 60.9% (R^2 =0.6091) of the variation in the log of maize is explained by the log of average temperature, annual rainfall and organic matter (proxy for soil fertility). The remaining percentage (39.1%) could be attributed to other factors such as seed varieties, method of cultivation etc. The annual rainfall (p< .0319) and organic matter (p< .347) are statistically significant at 5% and positively contribute to maize production. The result therefore implies that a 1% increase in soil organic matter, holding other variables constant, results in a 1.9% increase in maize production whereas a 1% increase in rainfall, holding other variables constant leads to a 0.7% increase in maize production. Thus, the regression of rainfall variability and maize production indicate that, as rainfall increases maize production begins to increase. This clearly validates the study objective on the influence of observed climatic trends on food crop production. However, the average temperature is not statistically significant even at 10% significance level. This may be attributed to less variation in the average temperature (Coefficient of variation= 0.0155) during the study period (1999-2013). In general, the estimation shows that maize production in the Municipality is principally dependent on rainfall and organic matter. Thus, indicating the influence of climate variables on food crop production.

4.2.5.3 Regression results of millet production

Using the Breusch-Pagan-Godfrey test to determine heteroscedasticity in the model for millet, the result presented in Table 4.15 (Page, 87) shows that heteroscedasticity is not statistically significant at 5% for millet production indicating that there is no heteroscedasticity. This suggests that the variance of error term is constant.

Table 4.15: Diagnostic test statistics for millet production

Diagnosis	Test-Statistics	Probability
Heteroscedasticity	5.8669	0.2109
Autocorrelation	2.0130	0.1560
Normality	2.8627	0.2389

Source: E-Views estimation by author, 2015

Similarly, the diagnostic result for autocorrelation among the residuals of the independent variables shows that there is no autocorrelation among the residuals of regression model for millet production (Table 4.15). The test for normality of the residuals also indicates that the residuals are normally distributed. The results presented in Table 4.15 indicate that the regression model is devoid of serious problems that may affect the findings for millet production.

Table 4.16 shows the results of the log-linear regression model used for estimating the influence of climatic variables (mean annual temperature and annual rainfall) and organic matter (proxy for soil fertility) on millet production. The F- statistics, is statistically significant at 5% level (p<.0444).

Table 4.16: Regression statistics for millet production

Variable	Coefficient	Standard Error	T-Statistics	Probability
Constant	-5.155400	31.74246	-0.162413	0.8739
LnaverageTemp	8.268311	9.015681	0.917103	0.3788
LnRainfall	-0.043149	0.306036	-0.140992	0.8904
LnOrganicmatter	2.595624	0.875195	2.965767	0.0128*

R Squared=0.5060; Adjusted R Squared=0.3712 and F-Statistics= 3.7552 (p< .0444)

**. Regression is significant at the 0.05 level.* Source: E-Views Estimation by author, 2015

This means that the explanatory variables specified in the millet production model are jointly significant. In other words, annual rainfall, average temperature and organic matter are jointly significant. From Table 4.16, about 50.6% (R^2= 0.5060) of the variation in the log of millet is explained by the log of average temperature, annual rainfall and organic matter. The remaining percentage (49.4%) could be attributed to other factors such as seed varieties, method of cultivation etc. The results further reveal that organic matter is statistically significant with a P-value of 0.0128 (Table 4.16). The implication is that a 1% increase in organic matter, holding other variables constant, leads to a 2.6% increase in millet production.

However, average temperature and rainfall are not statistically significant. This may be attributed to less variation in average temperature (Coefficient of variation= 0.0155) during the study period (1999-2013) and less rainfall required for millet cultivation. The results confirm the findings of Amikuzuno and Donkoh (2012) and Tunde *et al.* (2011) who noted that, millet production in Northern Ghana and the Kwara State in Nigeria appear to be insensitive to low rainfall respectively. Thus, low level of rainfall does not necessarily reduce millet production. The estimation therefore shows that millet production in the Municipality is highly dependent on organic matter. It could, therefore, be concluded that rainfall and temperature were not significant in explaining the variation in millet output in the Municipality during the 15 year period.

Generally, the regression results presented in this section show that rainfall has positive effect on maize production. On the basis of this, the study failed to reject the alternative hypothesis that rainfall exerts positive effects that are statistically significant on staple foods in the Bawku Municipality. On the contrary, the study failed to reject the null hypothesis that temperature does not exert significant effects on staple foods because the regression results showed that temperature has no effect on staple foods in the Municipality.

4.2.6 Farmers' observations on the effects of climate variation on food crop production

4.2.6.1 Farmers' observations on the effects of rainfall variability on food crop production

Based on respondents' experiences, all the farmers interviewed agreed that the manifestations of rainfall variability have adversely affected crop production, especially the main staple crops. A male respondent aged 57 explained that:

> "*...when I started farming, the rains usually came in the fourth and fifth months of the year (April/May) which was the time for land preparation (tilling) and sometimes for planting. This normally supported the cultivation of several crops. But these days, the rains come and go at any time. Sometimes the rains don't come until the eighth or ninth month of the year making it difficult to plant millet, sorghum, maize, rice and other crops. In fact, it is not easy to predict when the rains will come and stop. I am particularly worried about what will happen to my farming business in the future because that is what I depend on"*(Focus group discussion, 2014).

All the respondents (100%) argued that the manifestations of rainfall variability has affected the growing season in the past 15 years. Also, nearly all the respondents (93%) were of the view that the manifestations of rainfall variability have reduced the length of the growing season while the remaining respondents (7%) observed irregularities in the length of the growing season. All the respondents (7%) who observed irregularities in the length of the growing season reported that crop yield were moderately reduced. More than 76 % and 16% of those who reported a reduction in the length of the growing season also reported that crop yields were severely and moderately reduced respectively. The responses differed among the study communities. For instance, all the respondents in *Gozesi* and *Gentiga* pointed out that the reduction in the length of the growing season has severely reduced crop yields whereas respondents in *Mognori* (10.7%), *Zabugu* (1.9%) and *Kuka* (3.7%) reported that crop yields have reduced moderately (Figure 4.10; page, 90)

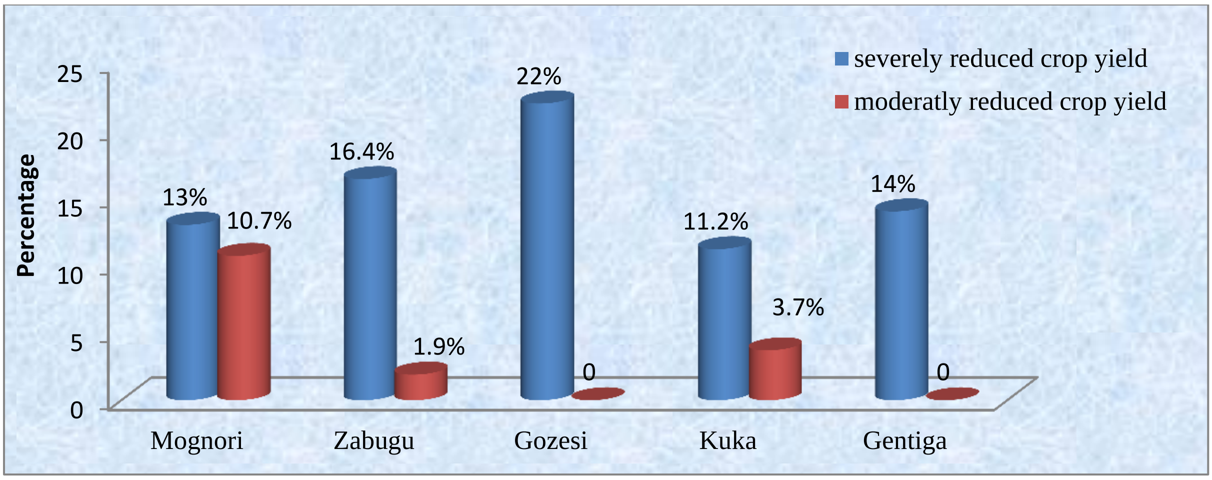


Figure 4.10: Respondents view on the effect of growing season on crop yields

Source: Field Survey, 2014.

Although most respondents attributed the reduction in crop yield to a shorter growing season, discussants of focus groups from the selected communities acknowledged factors such as farm pests and diseases, wrong use of fertilizer, outmoded farm practices, inadequate funds and inter-tribal conflicts as some of the major factors affecting crop production. The above non climatic factors coupled with low rainfall amount and frequent droughts have the propensity to worsen food insecurity among the most vulnerable households in the Municipality (Tunde *et al.*, 2011 and Fosu-Mensah, 2012).

From the results, respondents' observations of the effect of rainfall variability on food crop production are consistent with the regression results for maize production but inconsistent with rice and millet production. The inconsistency may be due to the influence of non-climatic factors outlined by the farmers on food crop production. Drawing on the results of the regression analysis and respondents observations of the effect of rainfall variability on food crop production, it can be argued that rainfall variability for the 15 year period had a significant influence on the variation of food crop production in the Municipality.

4.2.6.2 Farmers observations on the effects of temperature variability on food crop production

All the farmers (86.4%) who had observed temperature variability in the past 15 years were of the view that the manifestations of temperature variability negatively affect crop production especially maize production. Out of the 86.4% respondents who claimed that temperature variability had badly affected crop production, 23.4%, 22.9%, 15.9%, 11.7% and 12.6% were from *Mognori*, *Zabugu*, Gozesi, *Kuka* and *Gentiga* respectively (Figure 4.11). These farmers asserted that there was a reduction in maize yield. Several studies have demonstrated similar results. For instance, Lobel *et al.* (2011), Ramadoss *et al.* (2004), Gornall *et al.* (2010) and Cooper *et al.* (2009) observed that temperature increase above the requirement of between 30°C - 34°C for maize production would reduce maize yield significantly.

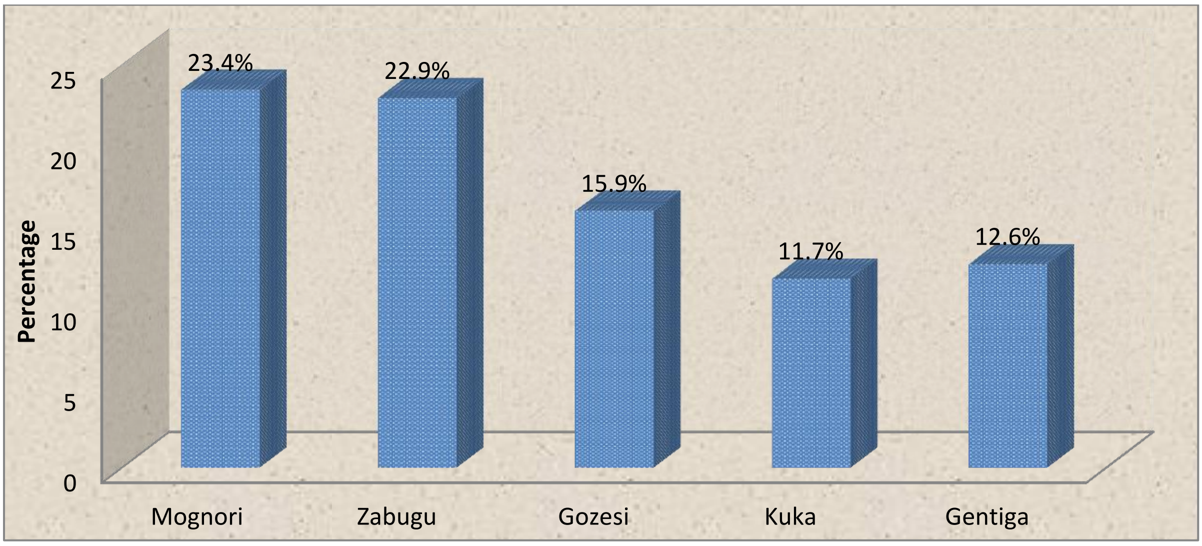


Figure 4.11: Respondents view on the effect of temperature variability on crop production

Source: Field Survey, 2014

In support of the above findings, an interview with officials of MoFA and SARI revealed that high temperatures during the main cropping and dry season gardening lead to low yields of crops like maize, sorghum, onions, groundnut and other vegetables as a result of stunted growth. The official from SARI explained that high temperatures during the growing season negatively affect the respiration and transpiration of plants and in turn affect plants' development and yield. This assertion is also buttressed by Fosu-Mensah (2012) and McCarl (2006) whose findings revealed that, high temperatures influence the respiration needs and raises water demand for plant growth. Consequently, these factors will affect crop development and reduce crop yield (Challinor *et al.,* 2004).

Upon probing further to find out other possible factors responsible for low yield or crop failure, discussants of focus groups from the selected communities outlined poor farm practices, poor seeds and misapplication of fertilizers as the overriding factors that may affect crop production. Despite the adverse effects of temperature variability on food crop production revealed by the survey, discussants of focus group at *Zabugu*, explained that some cereals such as millet and cowpea thrive well under high temperatures with little amount of water. As a result, more cowpea and millet are being produced in recent times. This confirms the findings of Kumar *et al.* (2013), Fosu-Mensah (2012) and EPA (2008) that millet and other drought tolerant crops are well adapted to high temperatures.

Similarly, some discussants at *Gentiga* and *Gozesi* also argued that increased temperature during the harvest time helps reduce post-harvest losses of some cereals like maize, cowpea, sorghum, rice etc. The results revealed by the respondents on the effects of temperature variability on food crop production supports the conceptual framework in section 2.7 of chapter two that variables of climate variability may have both negative and positive implications on food crop production.

In general, the respondents in the Municipality seem to have noticed that, temperature variability has negatively affects maize production. However, the regression results indicate that mean temperature variation had no significant effects on the major food crop production.

The discrepancy between farmers' observations and the regression results may be as a result of the use of the mean annual temperature that mostly conceals daily extremes. In addition, the disparity may also be due to the influence of non-climatic factors outlined by farmers on food crop production.

In spite of this, it can be concluded from the results presented in this chapter that observed climatic trends for the 15-year period had a significant influence on the variation of food crop production in the Municipality. Furthermore, the results presented in this chapter do not only validate the study objective on the influence of observed climatic trends on food crop production but also provide answers to the research question on the effects of observed climatic trends on food crop production.

4.3 Chapter Summary

This chapter analysed the influence of observed climatic trends on food crop production in the Bawku Municipality. The study revealed a decreasing trend with significant variation in the rainfall pattern while mean temperature showed a marginal decreasing trend with less variation over the 15 year period. The results further revealed that farmers have experienced climate variability and extreme climatic events in the past 15 years. The exposure of farmers to climate variability is an indication of their vulnerability to climate variability. As such it is important that adaptation measures should be stimulated towards addressing the adverse effects of climate variability.

The multiple regression model used to capture the influence of climate variables on food crop production revealed that rainfall and organic matter had a significant influence on maize production. Thus, maize production in the Municipality is mainly dependent on rainfall and organic matter. Similar to previous reports, mean temperature and rainfall had no significant influence on millet and rice production in the Municipality. Nonetheless, organic matter and soil pH had significant influence on millet and rice production respectively. The prevailing evidence from the regression results suggests that temperature variation within the 15 year period had no significant influence on food crop production in the Municipality.

The results point to the need for effective ways to be adapted to a more uncertain rainfall pattern in the Municipality. Based on the socio-demographic characteristics of the respondents a sustainable adaptation is far beyond the farmer. One key focus to ensure sustainable crop production in the Municipality is a much stronger commitment from the Municipal Assembly to negotiate and reach an agreement with civil societies, NGOs as well as farmers to put in place pragmatic and effective adaptation measures. Not only will this option seek the concerns of farmers, it will also build the adaptive capacity of farmers in the Municipality.

CHAPTER FIVE

FARMERS' VULNERABILITY AND ADAPTATION STRATEGIES TO CLIMATE VARIABILITY

5.0 Introduction

This chapter presents the results and discussions on farmers' vulnerability and adaptation to climate variability in the Bawku Municipality. The chapter is organised into two broad sections. Section one illuminates the vulnerability of food crop famers to climate variability. Section two presents the adaptation strategies employed by food crop farmers to climate variability.

5.1 Vulnerability of Food Crop Farmers to Climate Variability

The vulnerability to climate change and variability of local communities are among other aspects influenced by livelihood assets (Lyimo and Kangalawe, 2010). This is because vulnerability cannot be explained by biophysical factors alone (Cutter *et al.*, 2000) but also by their adaptive capacity which is influenced by their livelihood assets (O'Brien *et al*., 2004; cited in Thornton *et al.*, 2010). The more assets people have the less vulnerable they are. On the contrary, the greater the wearing down or less assets people have, the greater their vulnerability (Gbetibouo and Ringler, 2009). This section therefore describes farmers' vulnerability to climate variability based on their livelihood assets (social, financial, physical) and livelihood vulnerability.

The vulnerability of farmers to climate variability based on social assets seeks to find out farmers accessibility to social assets such as social relations, associations or unions and affiliations. According to Oremo (2013), farmers' affiliation to an association is central to the development of their adaptive capacity. Based on that, social affiliation to an association was used as an indicator for farmers' social assets. Table 5.1 (Page 96) shows farmers social affiliation to an association in the Municipality. Out of the total sample size (214 farmers) interviewed, 50 of the farmers representing 23.4% belonged to an association. The remaining 164 farmers representing 76.6% did not belong to any association.

Table 5.1: Respondents social affiliation to an association

Response	***Mognori***		***Zabugu***		**Gozesi**		***Kuka***		***Gentiga***		**Total**	**Percentage**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Yes	15	7	11	5.1	8	3.7	12	5.6	4	1.9	**50**	**23.4**
No	36	16.8	44	20.5	39	18.2	19	8.9	26	12.1	**164**	**76.6**
Total	**51**	**23.8**	**55**	**25.7**	**47**	**22.0**	**31**	**14.5**	**30**	**14.0**	**214**	**100**

Source: Field Survey, 2014

Farmers who belonged to an association or group cited food stuff, money, fertilizer and seeds as some of the benefits or help gained from belonging to the association. At the community level, *Mognori* showed the highest number of farmers (15) who belonged to an association followed by *Kuka* (12 farmers). *Gentiga* had the lowest number of farmers (4) who belonged to an association. The small number of farmers who belonged to an association at *Gentiga* reflects their limitation of coping with climate variability.

In a focus group discussion at Gozesi, it was revealed that mistrust was hindering some of the farmers from joining any association or group. Some discussants at *Gentiga* lamented that it is a total waste of time to join any association or group because when there is any help or relief items just a few members get to benefit from them. Discussants at *Mognori* and *Zabugu* also argued from a political point of view. They claimed that if one does not belong to the ruling party, it becomes difficult to get assistance from the Municipal Assembly. According to them, help or any assistance is first given to the members of the ruling party, relatives and friends before any other person. These problems outlined by the farmers not only have the tendency to erode community spirit and break social integration among farmers but also violates the stance of the capability theorists such as Amartya Sen and Catriona Mackenzie who argue that the political aim of justice in a society is to ensure equal access to a wide range of opportunities (Mackenzie *et al.,* 2014). The end result is restricting the range of social support that most individual farmers can access. This will further increase farmers' vulnerability since their ability to adapt or cope with climate variability will be limited. This supports the assertion of Ruijs *et al.* (2010) that low level of coping capacity results in high level of vulnerability. The outcome of the responses shows that the majority of the farmers in the Municipality are likely to be more vulnerable to climate variability due to their non-affiliation to any association. These farmers' ability to adapt or cope which is considered by Smit and Wandel (2006) as a crucial ingredient to determine vulnerability will be limited due to farmers' lack of social support.

The availability and accessibility to financial assets are preconditions for farmers to be able to cope with climate variability and extreme climatic events by strengthening existing livelihoods or diversify to new strategies. Access to credit from financial institutions, remittances from family and friends, and ownership of livestock/poultry were considered as indicators of farmers' financial assets. When the respondents were asked whether they have access to credit from any financial institutions, only 9.3 % (Table 5.2) of the respondents interviewed had access to credit. Perhaps, due to the unpredictable nature of the farming business, financial institutions are reluctant to give them credit.

Table 5.2: Respondents access to credit from financial institutions

Response	***Mognori***		***Zabugu***		**Gozesi**		***Kuka***		***Gentiga***		**Total**	**Percentage**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Yes	7	3.3	2	0.9	4	1.9	6	2.8	1	0.5	**20**	**9.3**
No	44	20.5	53	24.8	43	20.1	25	11.7	29	13.5	**194**	**90.7**
Total	**51**	**23.8**	**55**	**25.7**	**47**	**22.0**	**31**	**14.5**	**30**	**14.0**	**214**	**100**

Source: Field Survey, 2014

Out of the 9.3 % who had access to credit, 7.9% of them had access to credit from micro finance (Susu operators) while 1.4% had access to credit from the banks. The small proportion of respondents who had access to credit from banks may be due to the inability of most farmers' to provide collateral and not belonging to farmers' cooperatives. Considering the responses, the majority of the farmers in the Municipality do not have access to credit from financial institutions. This confirms the findings of Amikuzuno and Donkoh (2012) which showed most farmers in the Sudan Savanna Zone do not have access to credit. In spite of the low percentage (9.3%) of respondents who had access to credit, the majority of them were from *Mognori* (3.3%) while 2.8% were from *Kuka*. Only one person from *Gentiga* had access to credit. From this, it may be assumed that most farmers at *Gentiga* are the most vulnerable because their inaccessibility to credit may limit the application of adaptation measures.

Given the importance of finance in terms of adaptation and agricultural development, the unavailability and inaccessibility of credit are major complex problems set to compound farmers' vulnerability to climate variability (Jennings and Magrath, 2009). These factors according to Kelbore (2011) influence farmers` production decisions. Ultimately, this affects their production level as well as the income generated from farming. Farmers were asked whether they have insured their farms and it was interesting to know that most farmers did not know what insurance means let alone to insure their food crops. The consequence of this is in line with the framework for the study (Figure 2.4 in Section 2.7 of Chapter two), inferably income of small scale farmers who are not protected by insurance may decline sharply. However, 74.7% (Table 5.3) of farmers interviewed had either livestock or poultry. Out of this percentage, 28.9% had poultry, 23.8% livestock while 21.5% had both livestock and poultry. Even though, the majority (28.9%) of the respondents owned poultry, it is important to note that the income from the sale of livestock is much higher than the sale of poultry. In this sense, it is likely that respondents who owned livestock especially cattle had a better chance of reducing their vulnerability than respondents who owned only poultry.

Table 5.3: Respondents ownership of livestock and poultry

Study communities	Poultry		Livestock		Poultry and livestock		Total	Percentage
	Freq	**%**	**Freq**	**%**	**Freq**	**%**		
Mognori	13	6	15	7	11	5.1	**39**	**18.2**
Zabugu	17	7.9	10	4.7	14	6.5	**41**	**19.2**
Gozesi	13	6.1	8	3.7	9	4.2	**30**	**14.1**
Kuka	10	4.7	6	2.8	5	2.3	**21**	**9.8**
Gentiga	9	4.2	12	5.6	7	3.3	**28**	**13.1**
Total	**62**	**28.9**	**51**	**23.8**	**46**	**21.5**	**159**	**74.3**

Source: Field Survey, 2014

Within this general picture, the results across the study communities show that out of the total number of respondents (23.8%) who had livestock, more than half (12.6%) of them were from *Mognori* (7%) and *Gentiga* (5.6%) with the least respondents from *Kuka* (2.8%); while the majority (7.9%) of the respondents who had poultry were from *Zabugu*. The spatial variation stems from the physical environment of these communities. For instance, *Zabugu* has a relatively vast land which promotes the extensive system (Free range) of poultry production. Field pasture in *Mognori* and *Gentiga* encourages the rearing of livestock. A comparison of the respondents' ownership of livestock and poultry among the five study communities shows that most respondents from *Kuka* were likely to be more susceptible to extreme climatic events than the other four communities.

Generally, having either livestock or poultry according to Khan *et al.* (2009) is very essential as it can serve as an insurance mechanism. The indication is that these respondents would have something to fall on for a period of time when there are extreme climatic events. Thus, most often, the poultry and livestock ownership becomes a survival strategy adopted by food crop farmers to flee from the extreme effects of climate variability (Oppong-Anane, 2006 cited in Wood, 2013). It was observed in *Mognori* and *Gentiga* that cattle were not only kept for food and cash but also were used for animal traction for land preparation.

Table 5.4 presents the number of farmers who received remittances from family and friends across the study communities. Remittances from family and friends offer means through which farmers can support themselves by building their livelihood strategies (Lyimo and Kangalawe, 2010). A high proportion of respondents (59.3%) who were interviewed claimed they do not receive any form of remittances whereas 40.7% of the respondents received remittances. Out of this percentage, majority (21%) of them were between the ages of 51 and 60.

Table 5.4: Remittances from family and friends

Study Communities	Age group								Total	Percentage
	25-30		30-41		41-50		51-60			
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Mognori	2	0.9	3	1.4	6	2.8	4	1.9	**15**	**7**
Zabugu	1	0.5	1	0.5	4	1.9	14	6.5	**20**	**9.3**
Gozesi	0	0	2	0.9	10	4.7	7	3.3	**19**	**8.9**
Kuka	1	0.5	4	1.9	2	0.9	11	5.1	**18**	**8.4**
Gentiga	0	0	3	1.4	3	1.4	9	4.2	**15**	**7**
Total	**4**	**1.9**	**13**	**6.1**	**25**	**11.9**	**45**	**21**	**87**	**40.7**

Source: Field Survey, 2014

The remittances received by respondents, between the ages of 51 and 60 years indicate that the elderly were supported by their family and friends. This group of respondents (51-60 years) pointed out that their remittances were in the form of food items and money. Discussants of focus group at *Zabugu* and *Gozesi* attested that the remittances were woefully inadequate to sustain them but, it is essential to acknowledge that remittances are critical resources for most farmers to escape the hardships posed by extreme climatic events (Lyimo and Kangalawe, 2010). The high proportion of respondents (59.3%) who did not receive remittances may not be able to cope with extreme climatic events. This may be greatly pronounced in *Mognori* (7%) and *Gentiga* (7%) than in *Zabugu* (9.3%), *Gozesi* (8.9%) and *Kuka* (8.4%) whose livelihoods may be less vulnerable to the effect of climatic related events.

The physical assets available to farmers enable them to function more productively. Based on that, respondents were asked whether they had access to water for irrigation. This was to determine farmers' susceptibility to rainfall variability and frequent short-term drought in the Municipality. Respondents who had access to water for irrigation are presented in Table 5.5.

Table 5.5: Respondents access to water for irrigation

Study Communities	**Source of water for irrigation**						**Total**
	Rainfall		**Dams**		**Dug out wells**		
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	
Mognori	24	11.2	15	7	12	5.6	51
Zabugu	40	18.7	2	0.9	13	6.1	55
Gozesi	39	18.2	2	0.9	6	2.8	47
Kuka	17	7.9	9	4.2	5	2.3	31
Gentiga	26	12.1	0	0	4	1.9	30
Total	**146**	**68.2**	**28**	**13.1**	**40**	**18.7**	**214**

Source: Field Survey, 2014

The majority (68.2%) of the respondents did not have access to irrigation facility. They solely rely on rainfall for irrigation without any basic irrigation infrastructure to support their crop production. This may be due to the fact that most farmers, in general, have low income and do not have access to credit from financial institutions and hence cannot afford to invest in irrigation technology. The rest of the respondents (31.8%) relied on dams (13.1%) and dug-out wells (18.7%) for the irrigation of their crops. Out of the 31.8% who had access to water for irrigation, 15%, 16.3%, 17.8%, 7.9% and 11.2% of the respondents were from *Mognori*, *Zabugu*, Gozesi, *Kuka* and *Gentiga* respectively Plate 5.1 (Page, 102) presents some irrigation facilities accessed by some farmers during the long dry season in the Bawku Municipality.

Plate 5.1: Irrigation facilities in the Bawku Municipality
Source: Field Photograph, 2014.

From field observations, a number of factors could be attributed to the spatial differential of farmers' access to water for irrigation. Firstly, it was observed that farmers' access to water was based on the availability of irrigation facilities. Therefore, at *Mognori*, *Zabugu* and *Kuka* where there were small scale irrigation schemes (dug-out wells and dams) most farmers had access to water for irrigation than *Gentiga* and Gozesi. Secondly, it was observed that farmers' possession of water pumping machines partly determined their accessibility to water for irrigation. For instance, a noticeable feature in *Mognori* and *Kuka* was the use of water pumping machines by some farmers to access water from dug-out wells and dams for irrigation. In line with this observation, some farmers in these communities who did not use irrigation water may be partly due to their non-possession of water pumping machines. Thirdly, it was observed at *Kuka* that some facilities such as dams were mostly empty during the long dry season. (see Plate 5.2; page, 103) This perhaps, denied some farmers access to water for irrigation in the community.

Plate 5.2: A dried up dam at *Kuka* during the dry season

Source: Field Photograph, 2014

Lastly, it was obvious from observation that the ability to acquire irrigable land close to the dam site was an integral part of accessing water for irrigation especially in the dry season. For instance, at *Kuka* some land owners near the dam site had given parcels of irrigable land at a fee to farmers for dry season gardening. According to the Director of MoFA, such parcels of land are conserved for the highest bidder. These observations not only reveal the spatial differentiation of farmers' access to water for irrigation, but also point to the unfolding challenges that limit farmers' accessibility to water for irrigation. This in turn, leaves some farmers more vulnerable to the harsh climatic conditions. In spite of these challenges, the results confirm the importance of irrigation facilities for sustainable crop production. This should be widely implemented (Nyantakyi-Frimpong, 2013) especially in areas where rainfall is highly unpredictable. Generally, the percentage of respondents (31.8%) that had access to irrigation facility in the Municipality is a clear indication that most farmers were highly susceptible to less rainfall and frequent drought especially in *Gentiga*. High sensitivity, herein as susceptibility, according to Gbetibouo and Ringler (2009), is an indication of farmers' vulnerability to climate variability.

According to Cardoso *et al.* (2010), availability and accessibility to climate/meteorological information is a prerequisite to assess and anticipate hazards and vulnerabilities. All the farmers (214 farmers representing 100%) interviewed stated that they do not have access to weather information which is a recipe for vulnerability to adverse effects of climate variability. Farmers' lack of access to weather information gives a clear answer to how vulnerable they are to climate variability and extreme climatic events. Notwithstanding, the majority (65.9%) of the farmers acknowledged the importance of climate/ weather forecast in crop production (Table 5.6.)

Table 5.6: Respondents' perception on the importance of climate/weather forecast in crop production by level of education

Study Communities	**Level of education**								**Total**	**Percentage**
	Primary School		**Middle School**		**Secondary School**		**Never been to School**			
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
Mognori	7	3.3	1	0.5	5	2.3	29	13.6	**42**	**19.6**
Zabugu	2	0.9	0	0	1	0.5	24	11.2	**27**	**12.6**
Gozesi	3	1.4	0	0	2	0.9	16	7.5	**21**	**9.8**
Kuka	5	2.3	1	0.5	2	2.3	22	10.3	**30**	**14**
Gentiga	2	0.9	0	0	0	0	19	8.9	**21**	**9.8**
Total	**19**	**8.9**	**2**	**0.9**	**10**	**4.7**	**110**	**51.4**	**141**	**65.9**

Source: Field Survey, 2014

A high percentage (19.6%) were from *Mognori* while 12.6%, 9.8%, 14% and 9.8 % were from *Zabugu*, Gozesi, *Kuka* and *Gentiga* respectively. Almost all the respondents (30) from *Kuka* held a strong view that access to climate information could hep them adapt to climate variability. This perhaps shows that most farmers at *Kuka* know the importance of climate/weather forecast in crop production.

Similarly, in focus group discussions at *Mognori* and *Kuka*, farmers pointed out that access to climate information/weather forecast would help them adjust planting dates, adopt new farming practices, know what type of crops to cultivate, stop farming and engage in other businesses. The views of these farmers are in line with Challinor *et al.* (2003) who argue that access to climate information and forecast would help farmers to make strategic decisions concerning their farm operations. The outcome indicates that farmers who would be informed stand a better chance of reducing their vulnerability to climate variability and would be less vulnerable to climate extremes. This implies that the central government through the Municipal Assembly and other stakeholders who are directly involved in ensuring agricultural sustainability would have to invest in climate research and disseminate the information to increase awareness of climate variability and its impacts (Figure 2.6 in section 2.6 of chapter two).

Contrary to the above information, 60 farmers representing 28% believed that access to weather forecast is not necessary when it comes to crop production. They argued that the climate information/weather forecasts may be misleading which will further worsen their exposure to extreme climatic events. The notion discerned by these farmers is critically relevant to the applicability of weather monitoring and forecasting as an effective adaptation strategy. About 7.5% of respondents did not know whether climate forecast is necessary in the cultivation of crops. In focus group discussions at *Zabugu* and Gozesi, some of the discussants thought that the cause of weather/climate variability is supernatural forces. They argued that lack of respect for ancestral gods and the secret killing of innocent people in the Municipality are the main causes of extreme climatic events. So its prediction cannot be easily known unless the people of Bawku change their behaviour. This perhaps, explains why most farmers in *Gozesi* and *Zabugu* believed that access to climate information was not necessary. The explanation given by these farmers could be attributed to their lack of education (80.8%) on climate variability/change and it is very important that these farmers are educated on such issues to enable them appreciate the need to have access to weather forecasts or information.

Overall, the results presented on farmers' livelihood assets (social physical and financial assets) provide a clear picture of the realities of farmers' vulnerability to climate variability and extreme climatic events. The low livelihood assets of most respondents especially those from *Gentiga* are illustrative of how vulnerable most farmers are in the Bawku Municipality. Relative to respondents at *Gentiga*, respondents from *Mognori* were least vulnerable to climate variability and extreme climatic events because of their high livelihood assets. The high livelihood assets of most farmers at *Mognori* provide them the opportunity to adapt to the negative effects of climate variability and extreme climatic events. In addition, the results presented support the interpretation of vulnerability in the climate variability and change as an end point approach where adaptive capacity determines vulnerability.

The study advanced further to find out the vulnerability of farmers' livelihoods to climate variability. This is because farmers' vulnerability to climate variability and extreme climatic events can further intensify their livelihood insecurity and, in turn, reduce their capacity to prepare for and respond to future disasters (UNFCCC, 2011). This may exacerbate their current vulnerability and play an important role in their future vulnerability. In the Bawku Municipality, food crop farmers' livelihoods are dependent on their crop yield (Acquah, 2011). Based on that, farmers were questioned on whether they had observed any reduction or increase in their crop yield. All the farmers (214 farmers) interviewed were of the view that there had been a massive reduction in their crop yield. Figure 5.1 (Page 107) shows how the reduction in crop yields as a result of climate variability had affected farmers' livelihoods. A series of revelations such as inability to afford three square meals (19.3%), reduced income level (44.7%) and inability to meet educational needs of children (14.7%) were outlined by the farmers. These negative ramifications have the tendency to lead to a steady depletion of household assets through the sale of available assets to meet their pressing needs.

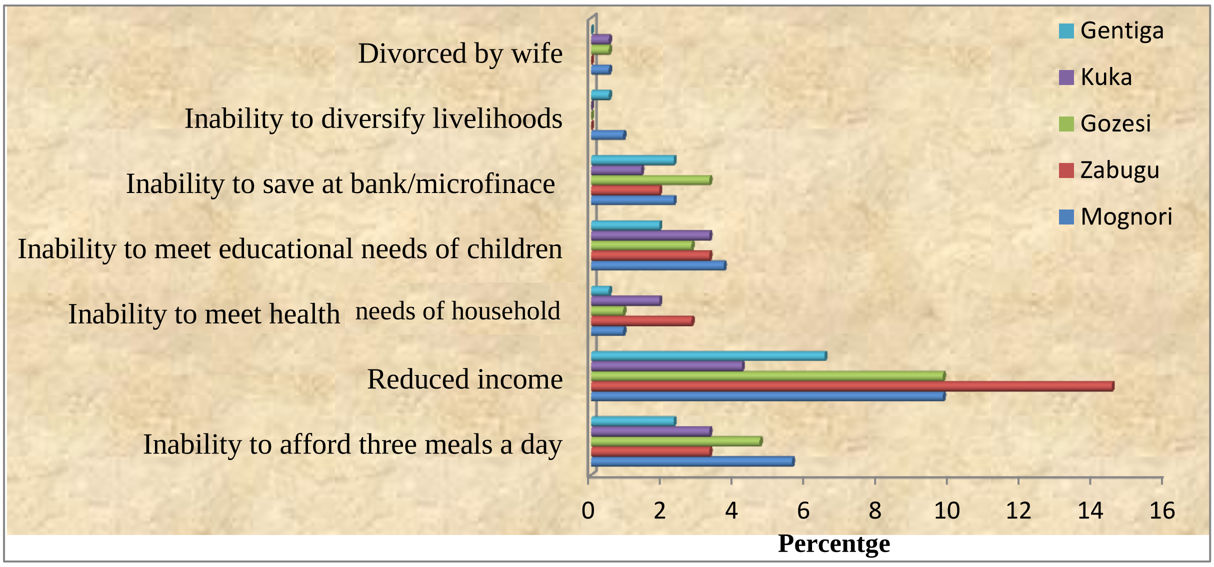


Figure 5.1: Respondents' view on how the reduction in crop yield has adversely affected their livelihoods

Source: Field survey, 2014

This would in turn, make farmers more susceptible to climate variability and extreme climatic events (UNFCCC, 2011 and FAO, 2008). Three male respondents (1.3%) also reported that their wives had divorced them due to their inability to provide for them. This highlights the extent to which climate variability and extreme climatic events negatively affect the social status of some male farmers. Consistent with all focus group discussions and responses from respondents, it was observed that climate variability has adversely affected the livelihoods of food crop farmers. In the context of spatial variation, reduced income was the most persistent problem mentioned across the five study communities. Respondents who could not diversify their livelihoods as result of reduced crop yield were only prominent in *Mognori* (0.9%) and *Gentiga* (0.5%). Out of the percentage of farmers who claimed they were not able to meet the health needs of their households, the majority were from *Zabugu* (2.8%) followed by *Kuka* (1.9%), *Mognori* (0.9%), *Gozesi* (0.9%) and *Gentiga* (0.5%). Respondents who could not afford three meals a day were greatly pronounced in *Mognori* (5.6%) and *Gozesi* (4.7%) with the least from *Gentiga* (2.3%). One male respondent each from *Mognori*, *Kuka* and *Gozesi* claimed their wives had divorced them. Inability to save with a bank/ microfinance company was cited most by respondents from *Gozesi* (3.3%), *Gentiga* (2.3%) and *Mognori* (2.3%). Respondents who cited inability to meet educational needs of children were almost similar across the study communities. The pattern of spatial distribution of how the reduction in crop yield has adversely affected farmers' livelihoods was not even. This indicates that the effect of reduced crop yield perpetuated by climate variability is multidimensional even within the same community. Similarly, summary of oral narratives (Box 5.1) from five farmers reaffirm how past climate variability and extreme climatic events have negatively affected their livelihoods. The oral narratives of these farmers illustrate the agonies some farmers have gone through as a result climate variability.

Box 5.1: Summary of oral narratives on Climate Variability on livelihoods

Source: Field survey, 2014

Con’t Box 5.1: Summary of oral narratives on Climate Variability on livelihoods

Source: Field survey, 2014

Predictably, from these narrations, the decline in crop yield is partly due to soil infertility as a result of continuous farming on the same piece of land for many years; farmers' inability to afford farm inputs such as fertilizers and pesticides due to high prices; their reliance on simple tools for cultivation; lack of financial support for farmers and large family size as in the case of Mr. Yusif who has three wives and eleven children to cater for. The outlined factors presuppose that, even seasons with enough rainfall for cultivation would insignificantly increase crop yields. The situation is further worsened due to frequent and prolonged droughts, sporadic rainfall, depletion of capital assets as evident in the case of Mr. Amobila and less adaptive capacity exhibited by the narrators. The consequences of these reflect in farmers' income which in turn has implication for their livelihoods as stated by the farmers. This may further increase their vulnerability.

Current livelihoods of these farmers rest not only on food crop production but on other activities and income sources of which substantial part comes from the support of spouse and children. Notwithstanding, it is also worth noting that some livelihood activities engaged in by these farmers as in the case of Mr. Anaba, creates a vicious cycle on the climate system. For example, the consequences of gathering firewood by Mr. Anaba according to Okali (2011) has the tendency to destroy the environment by way of depleting the forest which could have absolved some amount of carbon dioxide released into the atmosphere. This according to the framework (Figure 2.4 in section 2.7 of chapter 2) for the study would contribute to global warming and in effect may alter the climate, thus, acting as an agent of climate variability. This insight revealed by the narrative of Mr. Anaba further needs scientific inquiry in the Municipality.

In sum, from the oral narratives, the continuous decline of crop yield has depleted farmers' income level. This has crippled some farmers' ability to meet their daily expenses.

Considering the sensitivity of the Municipality to extreme climatic events; unless these farmers are supported, they would permanently remain vulnerable to climate variability and extreme events (Framework for the study, 2.4 of section 2.7 in chapter two).

Generally, the parallel responses from majority of the farmers revealed their low livelihood assets which the capability theorists describe as 'capability deficits.' These capability deficits according to Mackenzie *et al.* (2014) can signal sources of vulnerability. On the basis of the findings presented, it can be stated that most farmers in the Bawku Municipality are highly vulnerable to climate variability and extreme climatic events. However, the levels of vulnerability in the study communities were not homogeneous and were characterized by differential state of access to social, physical and financial assets. Therefore, assessing farmers' vulnerability to climate variability based on their livelihood assets (social, physical and financial); it may be assumed that farmers at *Gentiga* followed by *Kuka* were the most vulnerable to climate variability and extreme climatic events. This is because among the study communities, most farmers at *Gentiga* and *Kuka* had minimal livelihood assets. Minimal livelihood assets of a household according to Gbetibouo and Ringler (2009), fuels vulnerability of that household. The findings presented in this section, answers the research question on how vulnerable farmers are to climate variability and extreme climatic events. Moreover, the findings presented validate the second objective which sought to assess farmers' vulnerability to climate variability in the Bawku Municipality.

5.2 Adaptation Strategies of Food Crop Farmers in Response to Climate Variability

Adaptation strategy defines a situation in which farmers address the adverse effects of climate variability (IPCC, 2007). The intensity and frequency of climate variability in the Bawku Municipality merits an urgent need for adaptation from farmers, government and other stakeholders. Most studies have focused on general adaptation of farmers to climate variability without considering the difference between their coping and adaptation strategies. The study therefore sought to understand whether farmers have strategies in the short term (coping) and long term (adaptation) to deal with the adverse effects of climate variability. This is because a coping strategy may not always be effective in the long term when trying to deal with long periods of extreme climatic events. Table 5.7 presents the results of respondents who had short term adaptation strategies.

Table 5.7: Respondents' coping strategies to climate variability

Study Communities	**Migration**		**Adjustment in Planting date**		**Crop diversification**		**Irrigation**		**Change method of crop production**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Mognori	4	1.9	10	4.8	9	4.2	27	12.6	1	0.5	**51**
Zabugu	10	4.8	12	5.6	14	6.5	15	7	4	1.9	**55**
Gozesi	2	0.9	17	7.9	18	8.4	8	3.7	2	0.9	**47**
Kuka	6	2.8	8	3.7	3	1.4	14	6.5	0	0	**31**
Gentiga	2	0.9	23	10.7	1	0.5	4	1.9	0	0	**30**
Total	**24**	**11.2**	**70**	**32.7**	**45**	**21**	**68**	**31.8**	**7**	**3.3**	**214**

Source: Field Survey, 2014

The results indicate that all the respondents had a coping strategy, indicating that farmers have means of dealing with immediate negative effects of climate variability. The highest proportion of farmers (32.7 %) cited adjustment in planting date as their most effective coping strategy. This may be due to more dependence on rain for the cultivation of crops in the Municipality. While 31.8% of farmers resorted to irrigation as the most effective coping strategy, 21%, 3.3% and 11.2% of farmers also mentioned crop diversification to drought tolerant crops such as millet as well as vegetables such as onions, changed method of cultivation and migration as their most effective coping strategy to climate variability respectively. The lesser proportion of farmers who changed methods of cultivation as a coping strategy may be attributed to farmers' reliance on traditional methods of farming. Aside the dams and dug out wells as sources of water for irrigation, Kandji *et al.* (2006) and

MoFA (2010) observed that some farmers in Sudan Savanna Zone dig into the sand of dry riverbeds to get water for irrigation. This observation also holds true for *Mognori* and *Gentiga*.

The implementation of coping measures by farmers varied across the five communities. In *Mognori*, the majority (12.6%) of the farmers cited irrigation as their coping strategy. However, in *Gentiga*, change in planting dates (13%) was cited by most farmers as their coping strategy. Similarly, out of the respondents (21%) who cited crop diversification, 8.4% representing the majority were from Gosezi. The main reason accounting for the variation among the communities may be due to inadequate agricultural infrastructure such as irrigation facilities in some communities. For instance, *Mognori*, by virtue of its location along a river and the presence of dug-out wells had the advantage in accessing water for irrigation during drought periods than *Gentiga* which had no dam and limited dug-out wells. It is therefore not a surprise that, the majority of the farmers at *Gentiga* resorted to adjustments in planting date as a coping strategy. In addition, farmers' inadequate possession of financial and other livelihood assets may have limited their engagement in small scale irrigation.

With respect to gender and choice of coping strategies, it is evident from Table 5.8 that no female farmer resorted to migration and change of method of cultivation as coping strategies in response to climate variability and extreme climatic events.

Table 5.8: Respondents' coping strategies by sex

Sex	**Migration**		**Adjustment in Planting date**		**Crop diversification**		**Irrigation**		**Change method of crop production**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Female	0	0	22	10.3	18	8.4	11	5.1	0	0	**51**
Male	24	11.2	48	22.4	27	12.6	63	29.4	6	3.3	**163**
Total	**24**	**11.2**	**70**	**32.7**	**45**	**21**	**74**	**34.5**	**6**	**3.3**	**214**

Source: Field Survey, 2014

The role performed by women (taking care of children, household chores) perhaps influence and limits their choice of adaptation. The results also indicate that most farmers still apply tradition/indigenous knowledge in adapting to climate variability without any form of modern technology. However, Batterbury (2004) has explained that these traditional coping strategies can be improved upon through proper and systematic planning. It is important to think of ways in which these indigenous knowledge can be transformed to help build upon best adaptation practices in the Municipality to ensure sustainable agricultural development.

With regards to adaptation strategies, about 45% of the farmers had an adaptation strategy. Migration (26%) and trading (19%) were affirmed adaptation strategies in response to extreme climatic conditions especially during long periods of drought (Table 5.9).

Table 5.9: Respondents' adaptation strategies

Study Communities	**Migration**		**Trading**		**Total**	**Percentage**
	Freq	**%**	**Freq**	**%**		
Mognori	11	5.1	9	4.2	**20**	**9.3**
Zabugu	17	7.9	14	6.5	**31**	**14.5**
Gozesi	9	4.2	4	1.9	**13**	**6.1**
Kuka	13	6.1	10	4.6	**23**	**10.6**
Gentiga	6	2.8	3	1.4	**9**	**4.2**
Total	**56**	**26.2**	**40**	**18.7**	**96**	**44.9**
Age Group						
25-30years	21	**9.8**	0	**0**	21	**9.8**
31-40years	31	**14.5**	10	**4.6**	41	**19.2**
41-50years	4	**1.9**	27	**12.6**	31	**14.5**
51-60years	0	**0**	3	**1.4**	3	**1.4**
Total	**56**	**26.2**	**40**	**18.7**	**96**	**44.9**

Source: Field Survey, 2014

Out of the total percentage of farmers who resorted to migration, 5.1%, 5.6%, 4.2%, 6% and 2.8% were from *Mognori*, *Zabugu*, Gozesi, *Kuka* and *Gentiga* respectively. From Table 5.9, it is clear that, at least a farmer in each community had a long term strategy. Nonetheless, the adaptation strategies across the five communities showed that, the majority (14.5%) of the respondents in *Zabugu* had made more strides towards adaptation. The small proportion

(4.2%) of farmers in *Gentiga* who had adaptation measures implies that, the majority of the farmers in the community would be highly vulnerable to long periods of extreme climatic events.

The choice of adaptation can also be explained by the age of respondents. From Table 5.8, there is a direct relationship between the age of farmers and the adaptation strategy that farmers employed. For instance, the majority of the farmers (26.2%) who were within the age group of 25 to 50 years resorted to migration as an adaptation strategy to climate variability. None of the farmers aged above 50 years adopted migration. This was confirmed during a focus group discussion at *Zabugu*, when a discussant revealed that, those who migrate were mostly young farmers who can do any hard work. The older farmers (55 years and above) were mostly supported by their children and other relatives. The results substantiate the findings of Gbegeh and Akubuilo (2012 cited in Oremo, 2013) that the age of a farmer may influence the decision to adopt a particular adaptation strategy or another.

Generally, respondents who resorted to migration as both coping and adaptation strategies were of the view that migrating to other places or towns to work was very lucrative. According to these respondents, they sometimes made a lot of money which helped them in their farming business. They further explained that they were able to buy farm inputs such as fertilizer and employ other farm workers. A 38 year old farmer at *Zabugu* had this to say:

> *"I have personally benefited from this strategy, in 2010 the rains delayed and I travelled to Kumasi to look for a job. I got a job as a loading boy... I was able to accrue some money from my weekly income. I gave some to my wife to start a business and I also invested some into farming the following season... migrating to another place to look for a job is not easy but one has to do that to survive."*
> (Focus Group Discussion, 2014)

The results support the findings of Batterbury (2001) and Mortimore and Adams, (2001; cited in Kandji *et al.,* 2006) and the framework (See Figure 2.7 in section 2.7 of chapter two) that farmers are likely to embark on seasonal migration in an attempt to escape the hardship brought to them by climate variability. The FAO (2008) describes this seasonal migration as an opportunity for rural farmers and other farm workers to improve their livelihoods. However, migration as an adaptation strategy is particularly worrying because it may create an imbalance in development and other negative consequences such as urban slums and depopulation (Kandji *et al.,* 2006). Even though farmers were perturbed about the frequency and intensity of temperature and rainfall variation, the results show that the majority of the farmers interviewed did not have any long term plan and farm level adaptation strategies. This further re-enforces the view that, less adaptive capacity results in farmers' vulnerability to climate variability.

Nevertheless, given the small proportion of respondents who had long term adaptation strategies; the longer term benefits deemed significant, especially, during long period droughts. Considering the evidence on climate variability and extreme climatic events in the Municipality, it would have been most remarkable for most farmers in the Municipality to have a long term adaptation strategy which may translate into sustainable development of food crop production (See Figure 2.4. in Section 2.7 of Chapter two). This may reduce both current and future vulnerability.

Multiple livelihoods activities is a popular adaptation strategy which offer essential opportunities to ameliorate vulnerability of farmers (Lansigan *et al.,* 2000) when food crop production becomes more risky. However, the majority of the respondents (51.9%) did not have other sources of livelihood activities apart from farming. Table 5.10 (Page, 117) presents a summary of the respondents who did not have other sources of livelihood activities. Fourteen percent (14%) of the respondents who did not have other sources of livelihood activities explained that, they farm throughout the year since they engage in dry season farming too.

Table 5.10: Reasons why farmers did not have alternative livelihood activities

Study Communities	Dry Season Farming		Limit productive Time		Inadequate Finance		Total	Percentage
	Freq	**%**	**Freq**	**%**	**Freq**	**%**		
Mognori	20	9.3	0	0	4	1.9	**24**	**11.2**
Zabugu	2	0.9	4	1.9	19	8.9	**25**	**11.7**
Gozesi	0	0	0	0	32	14.9	**32**	**14.9**
Kuka	8	3.7	0	0	2	0.9	**10**	**4.7**
Gentiga	0	0	0	0	20	9.3	**20**	**9.3**
Total	**30**	**14**	**4**	**1.9**	**77**	**36**	**111**	**51.9**

Source: Field Survey, 2014

Out of the 14%, the majority (9.3%) were from *Mognori* while the minority (3.7%) were from *Kuka*. Dry season farming in these communities was due to the existence of dams and dug-out wells. Moreover, this has the potential of reducing vulnerability to climate variability. Nearly two percent (1.9%) of farmers who did not have alternative livelihood activities in *Zabugu* also claimed that, engaging in other livelihood activities limits productive time for farming and in turn affects crop production. In addition, 36% also maintained that, inadequate finance to start a business hinders their ability to engage in any sustainable livelihood activities. A larger percentage of farmers who cited inadequate finance were from Gosezi (15%) compared to the other four communities (11.2% for *Mognori*, 11.7% for *Zabugu*, 4.8% for *Kuka* and 9.3% for *Gentiga*). The varied responses by the farmers across the five communities demonstrate their level of adaptive capacity. On respondents who did not have alternative livelihoods, *Gentiga* and *Gozesi* stood out to be the least capable of managing climate variability and extreme climatic events. In the event of climate shock, respondents from *Zabugu* followed by *Mognori* and *Kuka* were better prepared to adjust to the adverse effects of climate variability and extreme climatic events than the others.

Respondents (48.1%) who had other sources of livelihood activities outlined trading (14%), poultry and livestock production (20%), janitorial work ("cleaner")(2.8 %), smock weaving (2.3%) and transport services (motor tricycle) (8.9%) as some of the livelihood activities they engaged in (Table 5.11). It is obvious from Table 5.11 that most of the farmers who had trading as their alternative livelihood activity were from *Kuka* (3.7%). This may be partly due to the presence of the Bugri market in *Kuka* and its proximity to the Asikiri market in *Zabugu*. This perhaps encourages trading in *Kuka*. The proportion of respondents who cited poultry and livestock production were relatively higher in *Zabugu* (7%). This could be related to the relative vast land in *Zabugu* which promotes poultry and livestock production. A high proportion of respondents who engaged in transport services (motorized tricycle) were in *Mognori* than the other four communities. The geographical location of *Mognori* far from the capital (Bawku) may have encouraged the use of motorized tricycle by some respondents to transport both humans and goods from *Mognori* to Bawku and other communities.

Table 5.11: Alternative livelihood activities of respondents

Alternative Livelihood Activities	*Mognori*		*Zabugu*		Gozesi		*Kuka*		*Gentiga*		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Trading	6	2.8	8	3.7	4	1.9	9	4.2	3	1.4	**30**
Poultry and Livestock Production	10	4.8	15	7	6	2.8	8	3.7	4	1.9	**43**
Janitorial Works	3	1.4	0	0	2	0.9	0	0	1	0.5	**6**
Smock Weaving	1	0.5	2	0.9	0	0	2	0.9	0	0	**5**
Transport Services (Motor Tricycle)	7	3.3	5	2.3	3	1.4	2	0.9	2	0.9	**19**
Total	**27**	**12.6**	**30**	**14**	**15**	**7**	**21**	**9.8**	**10**	**4.8**	**103**

Source: Field Survey, 2014

Generally, out of a total of 103 respondents who had alternative livelihood activities, 12.6%, 14%, 7%, 9.8% and 4.7% of the respondents were from *Mognori*, *Zabugu*, Gozesi, *Kuka* and *Gentiga* respectively. Considering the proportion of these farmers across the selected communities, it can be argued that there are few opportunities for farmers at *Gentiga* to diversify their livelihoods. This may be partly due to most farmers' assertion at *Gentiga* that inadequate finance to start a business hinders their ability to engage in alternative livelihood activity and partly due to the rural setting of *Gentiga*. Again, *Gentiga*'s geographical location which is far from the capital (Bawku) may have limited most respondents the opportunity to diversify their livelihoods. Remoteness to a market center has adverse influence on livelihood diversification and decrease the probability of non-farm employment for households (Khatun and Roy, 2012). In addition, the poor nature of roads connecting *Gentiga* to the market center presents a major constraint to livelihood diversification. It was observed that the residents of *Gentiga* had to cross a river to reach the main road leading to the market center. Some residents were seen carrying their items while wading through the river. This may have decreased the prospects of engagement in non-farm activities in *Gentiga*. What extricates farmers in *Zabugu* from the farmers in the other four communities is the relatively high degree of livelihood diversification due to its rapid suburbanization, presence of a market and its proximity to the capital of the Municipality. These attributes are important for selling food crop surpluses and also reflect the individuals' ability to diversify their livelihood activities.

Respondents who had alternative livelihood activities were asked to indicate whether their livelihood activities were sustainable or not. The majority (19.6%) of the farmers who had alternative livelihood activities reported that, their livelihood activities were sustainable (Table 5.12).

Table 5.12: The sustainability of the alternative livelihood activities

Alternative Livelihood Activities	**Very Sustainable**		**Sustainable**		**Not Sustainable**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	
Trading	4	1.9	15	7	11	5.1	**30**
Poultry and Livestock Production	6	2.8	15	7	22	10.3	**43**
Janitorial Works	2	0.9	4	1.9	0	0	**6**
Smock Weaving	0	0	1	0.5	4	1.9	**5**
Transport Services (Motor Tricycle)	12	5.6	7	3.3	0	0	**19**
Total	**24**	**11.2**	**42**	**19.6**	**37**	**17.3**	**103**

Source: Field Survey, 2014

Only 11.2% pointed out that their alternative livelihood activities were very sustainable whereas 17.3% were of the view that their alternative livelihood activities were not sustainable About 10.3% of the respondents who listed poultry and livestock as livelihood activity were of the opinion that such livelihood options are not sustainable since they are also affected by climate variability and extreme climatic events. The majority of these respondents were from *Zabugu* (2.8%) followed by *Kuka* (2.3%) and *Mognori* (2.3%). Nonetheless, these respondents claimed that they are better off with their poultry and livestock production than without them. Interestingly, 6.5% respondents with the majority (2.8%) from *Zabugu* also claimed that poultry and livestock production were sustainable and lucrative especially during the Eid al Fitr and Eid al Adha festivals when their demand is so high. This corroborates the findings of Stanturf *et al.* (2011) and Oppong-Ansah (2006 cited in Wood, 2013) that livestock rearing primarily in the northern savanna zones appears to be a viable livelihood diversification strategy for food crop farmers.

With regards to respondents who rendered transport services, 5.6% claimed that their livelihood activity was very sustainable, while 3.3% also claimed that the transport services were sustainable. Even though the percentage of respondents who engaged in the transport services was low, its sustainability was deemed to be very high across the study communities. This may be attributed to the fact that the motorized tricycle has emerged as an important and fast means of conveying both humans and goods from one place to the other within the Bawku Municipality especially during market days. However, the high cost of the motorized tricycle has an important implication on livelihood diversification. Seven percent (7%) of the respondents who engaged in trading were of the opinion that trading was sustainable while 4% claimed trading was very sustainable. The majority (2.8%) of these farmers were from *Kuka*. Likewise, from focus group discussions at *Mognori* and *Kuka*, it was observed that trading was deemed to be very sustainable depending on what one trades in and above all if one is very diligent on the business. A woman (farmer) at *Kuka* explained that:

> *"Depending on what you sell, it is possible to make a little money from it. Items such as water, clothes, food and soup mostly sell fast... as a trader it is important to cultivate the habit of saving (Susu) every day especially with a micro finance since you will have the chance of getting loan to expand your business. This is how I did it and now I have a shop where I sell almost everything."* (Focus group discussion, 2014)

The few respondents (2.8%) who got jobs as janitors at the Municipal Assembly were of the view that their livelihood options are very sustainable. They explained that as janitors they are paid every month for their services and the income generated is independent of climate events. According to them, though the money is not so much, it is better than nothing. Smock weaving was observed not to be sustainable. The respondents who engaged in smock weaving explained that the market for smock has declined due to high prices of the materials used in making the smock. In fact, some people had even stopped sewing them because the returns do no merit the tedious work involved in making them. Plate 5.3 depicts some of the alternative livelihood activities engaged in by respondents from *Mognori*.

A. Livestock production **B. Transport service (Motorized Tricycle)**

Plate 5.3: Livelihood activities engaged in by some farmers in the Bawku Municipality

Source: Field Photograph, 2014

The evidence from farmers who were engaged in other livelihood activities suggests that income generated from these activities have actually helped sustain their food crop production. This goes to support the framework (See Figure 2.4 in section 2.7 of chapter two) that effective adaptation strategies have the tendency to ensure sustainable agricultural development. Furthermore, from observation, about 13 farmers from the total sample size (214 farmers) adopted two or more adaptation strategies and this according to them has minimized the effects of climate variability on their livelihoods. On the basis of this, more than one adaptation strategy can be implemented by farmers to buffer their vulnerability to climate variability. But the issue perhaps would be limited funds to adopt two or more adaptation strategies.

Generally, given the array of adaptation strategies employed by farmers in the short and long terms, it can be concluded that some farmers have developed strategies in response to climate variability and extreme climatic events. However, further research is needed to determine the effectiveness and sustainability of these strategies especially in *Zabugu* and *Mognori* where most farmers demonstrated their ability to adapt to climate variability. More so, the study objective on examining the adaptation strategies employed by food crop farmers in the Bawku Municipality has been adequately validated by the results presented in this section.

According to Oremo (2013), socio-economic factors are important in the choice of alternative livelihood activities, particularly age, income and sex. From the study, the choice of alternative livelihood activities also had a gender element (Table 5.13).

Table 5.13: Alternative livelihood activities of respondents' from gender perspective.

Sex	**Trading**		**Poultry and livestock production**		**Janitorial works**		**Smock weaving**		**Transport Services (Motor Tricycle)**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
Male	7	3.3	43	20.1	5	2.3	5	2.3	19	8.9	79
Female	23	10.7	0	0	1	0.5	0	0	0	0	24
Total	**30**	**14**	**43**	**20.1**	**6**	**2.8**	**5**	**2.3**	**19**	**8.9**	**103**

Source: Field Survey, 2014

Out of the total respondents (30) who engaged in trading as an alternative livelihood activity, twenty three were females while seven were males. The female respondents mostly traded in food crops (rice, vegetables, etc) while the male respondents traded in kola nuts, beans, mobile phone accessories and used items such as clothes, belts and shoes. Only one female was a janitress, no female respondent cited poultry and livestock production, smock weaving and transport services (motor tricycle) as an alternative livelihood activity. The male respondents resorted to poultry and livestock production, smock weaving, transport services (motor tricycle) and janitorial work. The findings suggest that females are more likely to engage in trading as an alternative livelihood activity than male farmers. Similarly, livelihood activities which are labour intensive are presumed to be done by males. This indicates that gender influences the choice of multiple livelihood activities in the Municipality.

Furthermore, from the age group perspective, none of the respondents aged between 25-30 years engaged in trading; they resorted to poultry production, janitorial work and transport services (motor tricycle) as their alternative livelihood activities (Table 5.14).

Table 5.14: Alternative livelihood activities of respondents' from age group and income perspective.

Age Group	**Trading**		**Poultry and livestock production**		**Janitorial works**		**Smock weaving**		**Transport Services (Motor Tricycle)**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	
25-30years	0	0	2	0.9	4	1.9	0	0	12	5.6	18
31-40years	6	2.8	10	4.8	2	0.9	0	0	4	1.9	22
41-50years	23	10.7	14	6.5	0	0	1	0.5	2	0.9	40
51-60years	1	0.5	17	7.9	0	0	4	1.9	1	0.5	24
Total	**30**	**14**	**43**	**20**	**6**	**2.8**	**5**	**2.3**	**19**	**8.9**	**103**
Income per Month											
GH₵ 20-40	4	1.9	6	2.8	0	0	0	0	0	0	10
GH₵ 40-60	10	4.7	4	1.9	0	0	1	0.5	3	1.4	18
GH₵ 60-100	8	3.7	15	7	0	0	3	1.4	6	2.8	32
GH₵ 100- 200	5	2.3	11	5.1	4	1.9	1	0.5	4	1.9	25
GH₵ 200-300	3	1.4	4	1.9	2	0.9	0	0	4	1.9	13
Above GH₵ 300	0	0	3	1.4	0	0	0	0	2	0.9	5
Total	**30**	**14**	**43**	**20**	**6**	**2.8**	**5**	**2.3**	**19**	**8.9**	**103**

Source: Field Survey, 2014

However, the majority (31) of the respondents above 40 years had poultry and livestock production as their alternative livelihoods. A cross tabulation analysis of respondents' alternative livelihood activities and their income per month also confirmed that the majority of the respondents (93 farmers) representing 43.5% who engaged in other livelihood activities were those who earned a monthly income above forty Ghana Cedis (Table 5.1; page, 123). In this respect, alternative/multiple livelihood activities are essential to augment income generated from farming (Khan *et al.*, 2009) and should be given institutional attention as a viable adaptation strategy to reduce farmers' vulnerability to climate variability especially during prolonged droughts.

Generally, the adaptation strategies employed by the respondents are similar to what other researchers have found. For instance, Simbarashe (2013**),** Nyantakyi-Frimpong (2013), Stanturf *et al.* (2011), Khan *et al.* (2009) and Batterbury (2004) found out in their respective studies that farmers resort to irrigation, livelihood diversification and crop diversification into drought tolerant crops, migration and adjustment in planting dates as strategies in adapting to climate variability. These strategies according Nyantakyi-Frimpong (2013) and Kandji *et al.* (2006), have yielded some positive results which have enabled some rural farmers to function. Being able to function is what is ethically significant in the capability approach to adaptation. Therefore, farmers' ability to adapt to climate variability exhibits their resourcefulness to address their vulnerabilities.

According to Sand (2012), vulnerability of farmers could be curtailed by increasing and enhancing their adaptive capacity to enable them create a functioning life which otherwise would have been denied by climate variability. Though the capability theory focuses on the individual's ability to adapt and transform; it further emphasizes on agents/institutions (stakeholders) to assist in removing obstacles (cultural, environmental, social etc) set to hinder the individuals in their attempt to lead a satisfactory life. Such agents or institutions enable individuals' freedom and autonomy to promote resilience and avert vulnerability. In this regard, it is important to note the support of institutions (public and private) towards farmers' adaptation to climate variability. Respondents were then asked to describe training programmes, if any, they had received from institutions. The intent was to focus on purposeful formal training that farmers had received from institutions to develop their adaptive capacity in response to climate variability. From Table 5.15, only 38.8% of the respondents had been trained by MoFA (12.1%), NGOs (19.2%) and SARI (7.5%)

Table 5.15: Respondents view on institutional support

Institutions	***Mognori***		***Zabugu***		**Gozesi**		***Kuka***		***Gentiga***		**Total**	**Percentage**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**		
MoFA	7	3.3	6	2.8	4	1.9	5	2.3	4	1.9	**26**	**12.1**
NGOs	10	4.7	8	3.7	5	2.3	12	5.6	6	2.8	**41**	**19.2**
SARI	5	2.3	3	1.4	3	1.4	3	1.4	2	0.9	**16**	**7.5**
Total	**22**	**10.3**	**17**	**7.9**	**13**	**6.1**	**19**	**8.8**	**12**	**5.6**	**83**	**38.8**

Source: Field Survey, 2014

The high proportion of respondents trained by NGOs may be due to their ability to get funds to organise training for farmers. The lesser percentage of respondents (38.8%) who have received training from institutions demonstrates that the majority of the farmers do not acknowledge the importance of the training/workshops especially in *Gentiga*.

Discussants of focus group in each community offered diverse stories on why farmers do not participate in training programmes. For example, discussants in *Gozesi* and *Zabugu* claimed that farmers are not well informed about the training/workshops being organised. Discussants in *Gentiga* argued that, the training would not have any positive impact on their crop yield, while discussants in *Mognori* and *Kuka* reported that the training/workshop schedule is inappropriate. According to them, the training/workshops are organised at the time when farmers are working on their farms. Hence, most farmers are reluctant to participate in such training programmes. Those who received training were asked to describe the kind of training received. The responses given by respondents include training on new methods of farming (5.6%), irrigation management (3.5%), fertilizer application (12.1%), soil management (3.7%), land preparation (6.5%), credit management (2.3%) and harvesting (5.1%). A beneficiary of a programme from *Mognori* commented that:

> *"Since I started applying what I learnt at a training programme, I have seen considerable improvement in my crop yield."* (Focus group discussion, 2014)

These training outlined by the farmers according to the capability theory, are the positive freedom that will provide opportunities and also reduce vulnerability. Access to these freedoms herein as the 'training' is necessary for farmers to acquire the capabilities they need to reduce their vulnerability to climate variability and extreme events. However, it was revealed during focus group discussions at *Gentiga* and *Zabugu* that the training they received had not improved their adaptive capacity. They based their argument on the fact that when they applied what was learnt, it yielded no positive results. Responding to this, a key informant from MoFA clarified the issue by saying that some farmers misapply what they are taught and this may sometimes lead to yield losses. It was also revealed during discussions at *Gozesi* and *Kuka* that some farmers who attended some training programmes do not apply what has been taught. They still adhered to the outmoded methods of farming because that is what they have been taught by their fathers. This sought to convey that organising training/workshops would not necessarily enhance farmers' adaptive capacity unless there is a way to overcome these challenges.

Generally, the responses of farmers (45%) showed some level of adaptive capacity to moderate their vulnerability to climate variability. This was largely observed in *Mognori* where 52.9% representing the majority of the respondents from the community demonstrated their ability to adapt to climate variability and extreme climatic events partly due to their proximity to a river and access to irrigable land. Obviously, most respondents from *Gentiga* and *Gozesi* exhibited their inability to adapt to climate variability. Evidence of this include less proportion of respondents who had alternative livelihood activities and long term adaptation strategies. As a complement to the evidence of less adaptive capacity, the results showed that it is not enough to only focus on the farmers' adaptation strategies and exclude their socio-demographic characteristics. Hence, it goes without saying that the socio-demographic characteristics influence farmers' ability to adapt to climate variability. From this it follows that the socio demographic characteristics may be an instrumental limitation or enhancement of farmers' capabilities to adapt to climate variability.

Considering the outcome of farmers' adaptation to climate variability in the Bawku Municipality, the majority (67.2%) of respondents cited financial constraints as the major challenge they face in the course of adapting to climate variability (Figure 5.2). This same story was told by the key informants in the Municipality (SARI, MoFA and GMA). According to them inadequate funds is hindering their activities as a valuable lens in ensuring agricultural development in the Municipality.

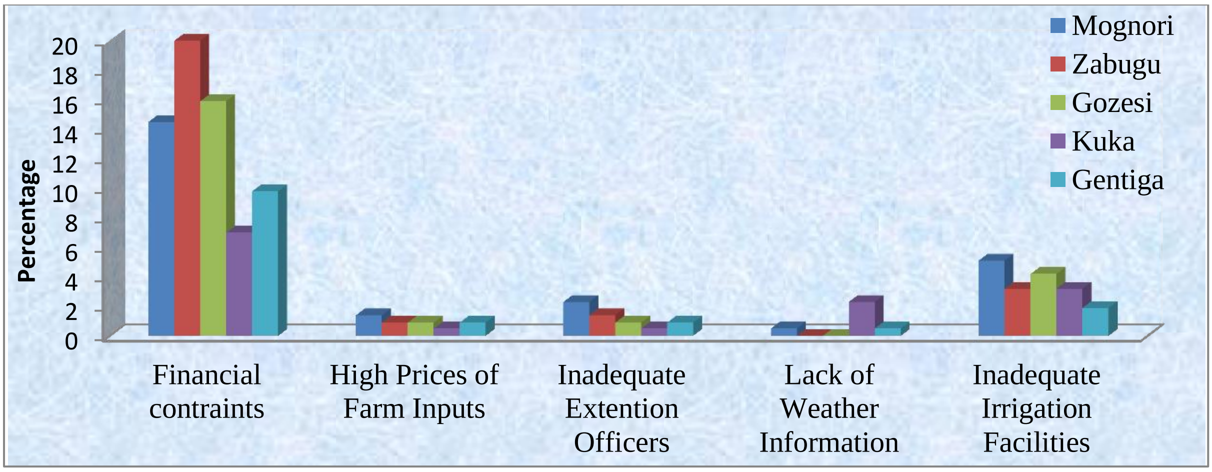


Figure 5.2: Challenges faced by respondents in their attempt to adapt to climate variability

Source: Field Survey, 2014

This goes to buttress the findings of Vidal (2009), Kandji *et al.* (2006) and Batterbury (2004) who reported that financial constraint is a major setback for farmers and institutions to adapt to climate variability. They observed that government's assistance that could relieve farmers of the hardship presented by the frequent weather variability and enable them to adapt is very limited. Aside the financial constraints, other challenges cited by the farmers included astronomical increase in the prices of farm inputs especially fertilizers (4.9%), inadequate irrigation facilities (17.5%), inadequate extension officers (7%), and lack of weather information (3.4%). Due to respondents' perturbation on the intensity and frequency of climate variability, some discussants of the focus groups argued that the availability of and accessibility to weather forecast will be of great help. According to them, such information will inform them on the type of crops and varieties that are most likely to flourish in the predicted growing season and the method of crop cultivation to adopt. The argument of these respondents is in line with the assertion of Challinor *et al.* (2003) that, availability and accessibility of climate information and forecast would help farmers to make strategic decisions concerning their farm operations. Moreover, taking into account the findings of Kabat *et al.* (2002) who observed that the utilization of weather forecast in the Nordeste region of Brazil led to an 18 % fall in grain production in 1992 as compared to 85% fall in 1987 when climate forecasts were not applied. It would be very vital to consider weather monitoring, forecasting and education for effective disaster and adaptation planning in the Municipality.

In addition, key informants enumerated inadequate skilled personnel, especially extension officers. They explained that the ratio of extension officers to farmers in the Municipality is so high (standard and acceptable ratio of 1: 200) that the extension officers are unable to attend to all the farmers in the Municipality. They also outlined inadequate logistics and the lack of farmers' co-operation as some institutional challenges they face in trying to help farmers adapt to climate variability. These institutional challenges further hinder farmers' ability to adapt to climate variability consequently compounding their vulnerability. The challenges enumerated by the key informants perhaps limit their ability to organise training/workshop programmes for farmers.

In the context of spatial variation, it is evident from Figure 5.2 (Page 127) that farmers who cited high prices of farm inputs were similar across the study communities. Lack of weather information seemed to pose no challenge to farmers from *Zabugu* and Gozesi. This is attributable to their perception that climate information/forecast may be misleading which would further worsen their exposure to climate variability and extreme climatic events. Even though, most respondents (21 respondents out of 30 respondents) in *Gentiga* did not have access to water for irrigation, only four respondents viewed lack of irrigation facility as a major hindrance to their adaptation. This further emphasizes the over reliance of farmers on rainfall for cultivation. A high proportion of respondents across the study communities cited financial constraints as the major challenge confronting them. This shows a favourable character towards the importance of adequate finance for farmers' adaptation to climate variability.

In response to how these challenges could be resolved, majority (52.4%) of the respondents cited financial assistance from the government, while the rest of the respondents were of the view that construction of irrigation facilities (13.2%), subsidizing the price of farm inputs (2%), recruitment of more extension officers (1.5%), provision of weather information/ forecast (2.4%) and praying to God (8.5%) were some possible solutions to the challenges posed by climate variability (Figure 5.3; page, 130). The responses vary spatially and stems from the challenges faced by the respondents from the study communities. For instance, among the high proportion (52.4%) of respondents across the study communities who cited government assistance, the majority were from *Zabugu* (23.4%) followed by *Mognori* (16.4%), *Gozesi* (15.9%), *Gentiga* (8.9%) and *Kuka* (8.4%). Among those who cited construction of irrigation facilities (13.2%), 4.6% were from *Mognori*, 4% from Gozesi, 2.3% from *Kuka* and I.4% each from *Zabugu* and *Gentiga*.

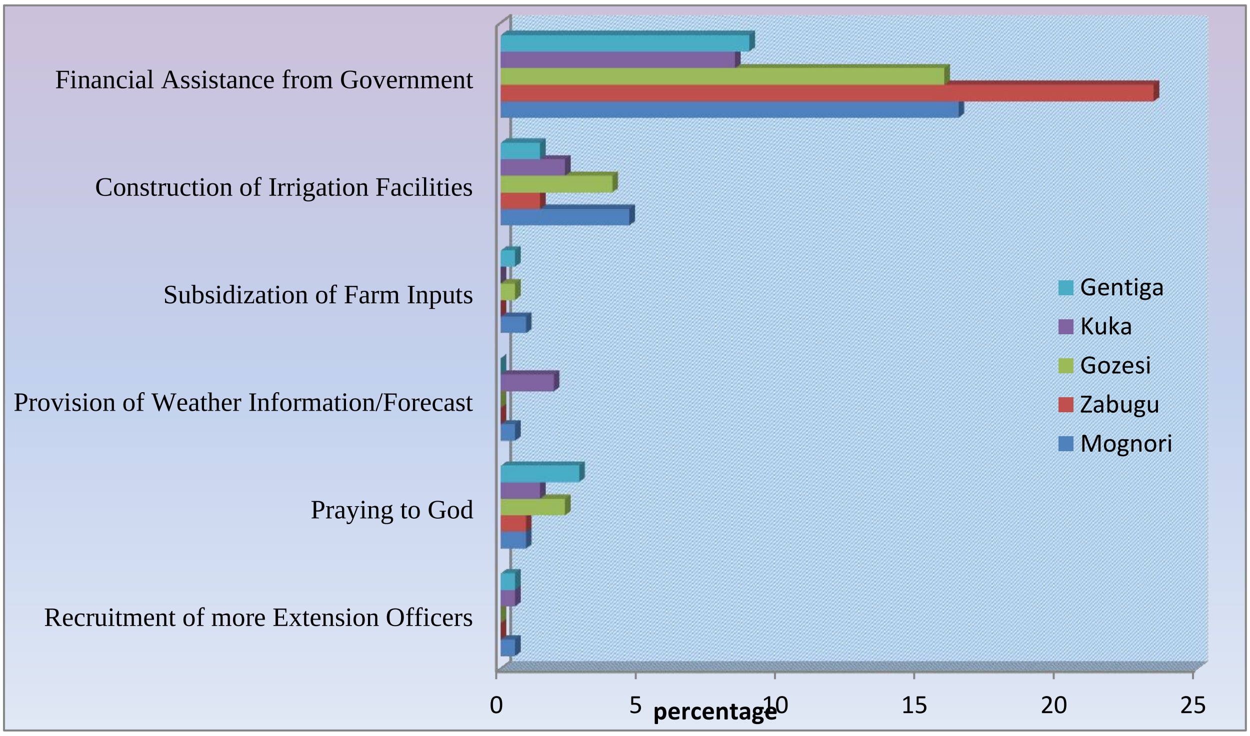


Figure 5.3: Solutions to the challenges faced by respondents in their attempt to adapt to climate variability

Source: Field Survey, 2014

Given the high proportion of farmers in *Zabugu* (18.7%) and *Gentiga* (12.1%) who relied on rainfall for food crop production, it was expected that the majority of the farmers would allude to the construction of irrigation facilities. None of the respondents from Gozesi, *Gentiga* and *Zabugu* mentioned provision of weather information/forecast as a possible solution to the challenges they face in their attempt to cope and adapt to climate variability and extreme climatic events. This is not a surprise since most of the farmers from Gozesi, *Gentiga* and *Zabugu* hold the perception that weather information/ forecast may be misleading.

Similarly, praying to God was claimed by most respondents at *Gentiga* (2.8%) and *Gozesi* (2.3%) as a potential solution to the challenges confronting them. This may be attributed to the fact that some respondents from *Gentiga* and *Gozesi* believed that, the cause of climate variability and extreme climatic events is the disobedience of man to instructions of the gods. Recruitment of more extension officers was cited by respondents at *Gentiga* (0.5%), *Kuka* (0.5%) and *Mognori* (0.5%). No respondent from *Gozesi* and *Zabugu* cited recruitment of extension officers as a solution to the problems they face. This is worrisome because it is assumed that most farmers do not see the importance of extension services in their farming activities. The implication is that most farmers would continue to lack the necessary technical skills and new technologies for ensuring food security in the Municipality. According to Gbetibouo and Ringler (2009), extension services enhance and influence the choice of farmers' adaptation to climate variability/change and expose farmers to new information and technical skills.

In addition, key informants also cited provision of logistics, recruitment of more extension officers, adequate funds and farmers' cooperation during field demonstration. In general, the responses were skewed towards adequate funds. This is because any effective adaptation strategy requires personal or borrowed funds. For instance, the construction of large and small irrigation facilities, adoption of technology or taking up both crop and livelihood diversification require large sum of money.

5.3 Chapter Summary

Prominent in the climate variability and change literature is the concern of vulnerability and adaptation. The analysis of vulnerability is underpinned on exposure, sensitivity and adaptive capacity. The study analysed the vulnerability and adaptation of food crop farmers to climate variability. The study revealed that farmers’ vulnerability to climate variability is manifested in their exposure, sensitivity and low adaptive capacity. However, farmers’ vulnerability to climate variability is spatially differentiated across the five study communities largely due to their level of adaptive capacity. This occurs in the context of their long term adaptive capacity. Respondents’ capability to adapt based on the results of the study is challenged by inadequate extension officers and irrigation facilities, high prices of farm inputs, financial constraints and lack of weather information. These findings suggest that the less adaptive capacity of farmers, the higher their vulnerability. This would worsen future vulnerability if efficient long term adaptation strategies are not implemented.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

In recent times, the issue of climate variability has gained much importance across the globe especially in the marginalised areas of the world. This is because of its significant influence on the environment (IPCC, 2012). Generally, the study focused on the effects of climate variability on food crop production in the Bawku Municipality. Specifically, the study tried to provide an understanding of the influence of climatic trends on food crop production, farmers' vulnerability to climate variability and farmers adaptation to climate variability. Based on the objectives, the study hypothesised that temperature exerts positive effects that are statistically significant on staple foods in the Bawku Municipality; and rainfall exerts positive effects that are statistically significant on staple foods in the Bawku Municipality.

The study employed the mixed method approach where quantitative methods were combined with appropriate qualitative methods. Cross sectional and time series study were adopted to explore the effects of climate variability on food crop production. Data collected for achieving the objectives were from both primary and secondary sources. This was through the use of questionnaires, focus group discussions, structured interview guides, oral narratives, field observations, journals articles, reports and documented records from government departments and institutions. The study made use of the simple random and purposive sampling techniques to identify the respondents. The respondents consisted of food crop farmers and officials from MoFA, GMA and SARI. Descriptive statistics was used to analysed quantitative data obtained from food crop farmers. Coefficient of variation was used to analyse rainfall, temperature and food crop variability in the Bawku Municipality. The multiple regression model was used to test the hypotheses and analyse the influence of observed climatic trend on food crop production. The qualitative data obtained were analyse thematically.

This chapter presents the summary of findings that emerged from the data analysis presented in chapters four and five and makes recommendations for addressing the problems investigated. The chapter is organised into three main sections. Section one discusses and summarises the emerging issues from the data analysis presented in chapters four and five. These issues are presented along the lines of the study objectives. Section two presents the conclusion drawnfrom key findings. Recommendations have been made in response to the findings in section three of this chapter.

6.1 Summary of Research Findings

6.1.1 Influence of observed climatic trends on food crop production.

With regards to the study objective on analyzing the influence of observed climatic trends on food crop production, analysis of the data showed that the Municipality received less than 1400 mm of annual rainfall for the 15 year period with a mean annual total of 901.9mm. The Sen's estimate (slope) for the period (1999-2013) showed that, the total annual rainfall amount is decreasing. The estimated annual anomaly of rainfall indicates that the amount of annual rainfall varied appreciably from year to year with a coefficient of variation (0.3343) for rainfall. The study revealed that, between 1999 and 2013 the Municipality experienced two major episodes of high rainfall above the baseline average (1999 and 2007), which may have affected food crop production. Farmers' observation of rainfall variability were in line with the meteorological data.

With regards to temperature variation, the meteorological data showed that mean annual maximum temperature varied between 33.6°C and 35.8°C with a total mean value of 35.6°C over the 15-year period. The minimum temperature oscillated between 21.2°C and 23.4°C with a mean value of 22.7°C. In spite of the significant variations in the inter-annual minimum and maximum temperatures in the Municipality, the mean annual temperature showed a very marginal variation. The coefficient of variation (0.0155) for the mean temperature (Maximum and Minimum) showed that temperature was less variable during the 15-year period (1999-2013). On the contrary, the study found out that respondents had observed temperature variation in the past 15 years. It was also revealed that drought and wind storms were not new phenomena but their frequency and intensity was a new challenge facing the Municipality. Moreover, drawing on the results from the study it was established that, the exposure of farmers to the manifestations of climate variability and extreme climatic events is an indication of their vulnerability to climate variability. Spatially, since respondents were within the same agro ecological zone (Sudan Savanna), it was assumed that respondents were exposed to the same level of climate anomaly especially drought (Eakin and Bojorquez-Tapia, 2008 cited in Antwi-Agyei *et al.*, 2012). Hence, their vulnerability in terms of drought exposure was similar across the study communities. However, respondents at *Mognori* were highly vulnerable to flood due to their location near a tributary of the White Volta.

The multiple regression model (ordinary least square) used to determine the influence of the observed climatic trends on food crop production indicated that rainfall was significant in explaining the variation of maize yield in the Municipality for the 15 year period. On the basis of this, the study failed to reject the alternative hypothesis that rainfall exerts positive effects that are statistically significant on staple foods in the Bawku Municipality. However, the study failed to reject the null hypothesis that, temperature exerts no significant effects on staple foods Bawku Municipality because it was not significant in explaining the variation of millet, maize and rice production. In spite of this, temperature still plays a crucial role in the agricultural sector. This is because when temperature exceeds the optimum required for plant growth, plants respond negatively with a steep drop in net growth and yield (Fosu-Mensah, 2012). The findings showed that climate variables (temperature and rainfall) do not have similar effects on all staple foods. In this regard, the influence of climatic variables varies across staple foods in Bawku Municipality. Further research is needed to support these claims. The results further indicated that, soil pH and organic matter which were considered as proxy for soil fertility were statistically significant and positively influence food crop production (rice, maize and millet). This implies that food crop production may gain from the improvement in the quality of the soil.

While some farmers noted that temperature and rainfall adversely affect food crop production, others also argued that high temperature has helped to reduce post-harvest losses in the Bawku Municipality. From the regression analysis on the influence of climatic trends on food crop production and farmers' response, the study concludes that observed climatic trends is responsible for variation in food crop yield. However, the study acknowledges the importance of other factors such as method of farming, fertilizer application, seed varieties, etc. in explaining the variation in food crop yield. The findings outlined answers the research question on what are the effects of observed climatic trend on food crop production. The findings adequately validate the study objective which sought to analyse the influence of observed climatic trends on food crop production in the Bawku Municipality.

6.1.2 Farmers vulnerability to Climate Variability

The study objective on assessing farmers' vulnerability to climate variability based on their livelihood assets (social, financial and physical assets) revealed that most farmers did not belong to an association largely because there is mistrust among them. Among the five communities, it was observed that *Gentiga* had the least number of farmers who belonged to an association. Most farmers did not have access to credit facility especially in *Gentiga*. Only one respondent in *Gentiga* had access to credit. The few who had access to credit facilities faced some challenges. This perhaps deter farmers from accessing funds from financial institutions. It was observed that farmers did not know what crop insurance meant let alone to insure their food crops against any misfortune.

However, most of the farmers had livestock, poultry or both which served as an insurance mechanism for them in times of low crop yields or crop failure. A greater proportion of the respondents in *Mognori* and *Gentiga* owned livestock with the least percentage from *Kuka*. A high percentage of farmers who owned poultry were from *Zabugu*. The spatial distribution shown is partly due to the physical environment of the communities. For instance, *Zabugu* has a relatively vast land which promotes the extensive system (free range) of poultry production. Field pasture in *Mognori* and *Gozesi* encouraged the rearing of livestock. Again, it was observed that most respondents did not receive remittances from family members. The few who receive remittances were the elderly (50 years and above). According to them, the remittances are woefully inadequate to sustain them. The results showed that there is not much difference in the proportion of the respondents who received remittances across the study communities. In terms of their physical assets, it was observed that few farmers had access to water for irrigation while most of them relied solely on rainfall for their crop cultivation especially in *Gentiga*. This is because of the absence of irrigation facilities especially in *Gentiga*, non-possession of water pumping machines and inability to acquire irrigable lands.

The small percentage of farmers who had access to water for irrigation is an indication of most farmers' susceptibility to long periods of drought. It was observed that all the farmers did not have access to climate information/ forecasts, however, most farmers were of the view that climate information/weather forecasts would help them make strategic decisions concerning their farm operations. Such decisions include; adjust planting date, adapt to new farming methods/practices, know what type of crops to cultivate, stop farming and engage in other businesses.

Moreover, it was observed that due to the manifestations of climate variability and extreme climatic events, crop yield had reduced drastically and most farmers were unable to afford three square meals and also meet the educational needs of their children as a result of low income level. On the basis of this, it was established that climate variability and extreme climatic events have adversely affected the livelihoods of food crop farmers in the study area. Drawing on these results and coupled with farmers' exposure to climate variability and extreme climate events, the study asserts that farmers in the Municipality are highly vulnerable to climate variability and extreme climatic events, particularly, among the majority of the respondents from *Gentiga* due to their low livelihood assets. Most respondents from *Mognori* were least vulnerable to climate variability and extreme climatic events due to their high livelihood assets. The results and findings validate the study objective on assessing the vulnerability of food crop farmers to climate variability and also answers the research question on how vulnerable food crop farmers are to climate variability.

6.1.3 Adaptation strategies of food crop farmers in response to climate variability

Drawing on the theoretical orientation of the capability approach to adaptation that explains individuals' ability to lead a functioning life; the last objective sought to understand whether farmers had strategies in the short and long term to deal with the adverse effects of climate variability to enable them lead a satisfactory life. It was observed that respondents had resorted to adjustment in planting dates, crop diversification to drought tolerant crops like millet as well as vegetables, irrigation, changed method of cultivation and migration as a short term strategy to climate variability. The coping strategies employed by the respondents varied among the study communities. For instance, at *Mognori*, the majority of the respondents cited irrigation as their coping strategy. However, changes in planting date was considered by most respondents from *Gentiga* as the most effective coping strategy. With regards to long term strategies, the majority of farmers did not have any adaptation strategies. Nonetheless, few respondents resorted to migration and trading as the most effective adaptation strategy in response to extreme climatic condition especially during long periods of drought. Regardless of the few respondents who had long term strategies, at least a farmer in each community had a long term adaptation strategy.

Alternative livelihoods activities offer essential opportunities to ameliorate vulnerability of farmers (Lansigan *et al.,* 2000). Nonetheless, the majority of the farmers did not engage in other sources of livelihood activities because of the following reasons: they farmed throughout the year, inadequate finance and time constraints. Respondents (48.6%) who engaged in other sources of livelihood activities outlined trading, poultry and livestock production, janitorial work (cleaner), smock weaving and rendering transport services using motorized tricycle. Most of the respondents who engaged in trading were from *Kuka* while the proportion of respondents who cited poultry and livestock production and those that offered transport services as well as janitorial works were relatively higher at *Zabugu* and *Mognori* respectively. The study observed that, some respondents engaged in more than one alternative livelihood. Given the range of adaptation strategies employed by the respondents, the study asserts that, farmers in the Municipality have developed strategies in response to climate variability and extreme climatic events. These strategies need policy interventions to ensure their effectiveness in the long term.

Based on theoretical exploration of the capability approach to adaptation that emphasizes on institutional support to individuals to adapt; the study discussed institutional support that farmers had ever received to enhance their adaptive capacity and it was observed that the majority of the respondents had not received training from any institution. The few respondents who had ever been trained outlined fertilizer application, soil management, land preparation techniques, credit management and harvesting as the training received. Furthermore, making these adaptation strategies sustainable present many challenges. The respondents indicated that financial constraints, astronomical increase in prices of farm inputs, inadequate irrigation facilities, inadequate extension officers and lack of weather information as the challenges hindering their ability to adapt. Considerations in making institutions effective in their role as agents to assist farmers to adapt is also hampered by financial constraints, inadequate logistics and lack of farmers co-operation. Financial support, provision of irrigation facilities, recruitment of extension officers, subsidies on farm inputs, praying to God and provision of weather information were suggested by respondents as the solutions to the challenges outlined.

6.2 Conclusion

Climate variability and extreme climatic events have been a long existing challenge to food crop farmers and it has become more complex because of its frequency and intensity (IPCC, 2012). Results from the regression model and farmers responses show that climate variables are contributory factors in explaining the variation in crop production. The frequent manifestations of climate variability and extreme climatic events indicate farmers' exposure to climate variability thereby signaling farmers' vulnerability to climate variability. Exploration of farmers' capital assets indicates that most farmers have low adaptive capacity. The image of low adaptive capacity reinforces farmers' vulnerability to climate variability.

The limited long term adaptation strategy in the Municipality is of concern because farmers vulnerability is likely to worsen when an unexpected long period of drought occur. In view of this, the study suggests that farmers' adaptation to climate variability should have a long term focus to deal with future extreme climatic events. Notwithstanding, the alternative/multiple livelihood activities employed by some respondents have helped them to sustain their crop production. These alternative/multiple livelihoods activities engaged in by farmers supplement the low income from farming. Even though farmers are making effort to adapt to the frequent climate variability in the Municipality, the study observed that institutional support has not made any significant impact on most famers' capability to adapt to climate variability and extreme climatic events due to the challenges they face. The challenges hindering both farmers and institutions are multi-factorial to farmers' vulnerability. Drawing on the results from the survey, a conclusion can be drawn that frequent climate variability and extreme climatic events, coupled with low adaptive capacity and institutional challenges erodes farmers' capability to lead a functioning life. Notwithstanding, the findings presented adequately validate the study objectives and clearly answers the research questions of the study.

6.3 Recommendations

The findings of this study have brought to light the insecurity of food crop production and the precarious conditions of farmers in the Bawku Municipality due to their exposure, sensitivity and low adaptive capacity to climate variability and extreme climatic events. These findings therefore call for pragmatic measures to reduce both current and future vulnerability of farmers to climate variability and extreme climatic events. This requires the following approaches:

Integrated approach to enhancing farmers capabilities

Food crop production is an important sector in the Bawku Municipality as it provides income, food and employment to the farmers. The sustainability of food crop production goes with numerous challenges of which climate variability and extreme climatic events are riding factors. Based on farmers low adaptive capacity there is the need to enhance farmers' capabilities. Enhancing farmers' capabilities in responding to extreme climatic events should be one of the topmost priorities of policy intervention. This could be achieved through more proactive and comprehensive integrated approach. For a sustainable development in food crop production all stakeholders including the farmer, community, Non-Governmental Organisations, development partners and the government must work together on a common platform under social, economic, political and environmental arena to help enhance farmers' capabilities. This would help alleviate the challenges presented by climate variability and extreme climatic events. This means that farmers' adaptive capacity should not be independent of the farmer and other stakeholders.

Education and capacity building

Education is vital in enhancing farmers' ability to adapt. There should be emphasis on farmer education on the importance of forming social groups or cooperatives and participation in training/workshop programmes. This will help inform the kind of adaptation strategy to be adopted. Again institutional capacity-building through training and workshop would help in the development of expertise for planning and implementing adaptation activities. The pursuance of just adaptation strategies without regard for education and capacity building poses a threat to effective adaptation. Therefore, education and capacity building should be one of the areas for policy intervention.

Funding for adaptation and insurance schemes

Funding is very important to farmers and other stakeholders for planning and implementation of adaptation strategies. Farmers in the Bawku Municipality have little capacity to adapt in terms of financial resources. Access to funds by farmers and support to institutions in the Municipality has been identified as complex. There is the need for stakeholders to collaborate with financial institutions to make funds readily available to food-crop farmers to enable them effectively adapt to climate variability. Most importantly, funds for adaptation should be sustained because without regular flow of funds, adaptation strategies run the risk of not being effectively addressed. In response to the realization that insurance can play a role in adaptation, there is the need for the introduction of insurance schemes to small holder farmers on the basis of their social groups or cooperatives.

Provision of infrastructure/logistics and weather information

Improvement of existing and provision of agricultural infrastructure such as irrigation facilities in the Bawku Municipality could go a long way to address this critical challenge. With the frequent climate variability and extreme climatic events, the provision of irrigation facilities should be considered by the Municipal Assembly as an alternative source of water for irrigation for food-crop production. This would encourage more farmers to farm during the long dry season. In addition, institutions should be equipped in terms of logistics and skilled personnel by the government and NGOs to enhance their operations to address the complexities of the implementation of adaptation action.

Moreover, the provision of weather information/forecasts to farmers is central to farmers' adaptation. This is because weather information has the tendency to influence farmers' decision on their farm operations. Drawing on the findings, the study recommends that farmers should be provided with reliable and timely information by the meteorological agency on weather patterns so as to reduce their shock to climate variability and extreme climatic events.

Research development

Owing to the sensitivity of the Bawku Municipality, in the long term, there should be emphasis on research development by the Municipal Assembly to help achieve sustainable development in food-crop production. Special funds must be allocated to conduct a comprehensive research. Research development must be tuned to realistic strategies that are context specific and from the farmer perspective. The study should focus on improving traditional methods of adaptation, technology-based adaptation, applicability of weather monitoring and forecasting on crop production and improvement of seed varieties and more importantly the effectiveness of adaptation strategies by farmers. This would inform the kind of national policy to adopt on farmers' adaptation to climate variability.

REFERENCES

Abtew, W., Pathak C., Scott Huebner, R. and Ciuca, V. (2009). "Hydrology of the south Florida environment. In 2009 South Florida Environmental Report, South Florida Water Management District, West Palm Beach, FL. Vol. I, Ch. 2.

Acquah, D. H. (2011). "Farmers perception and adaptation to climate change: A willingness to pay analysis," *Journal of Sustainable Development in Africa,* Vol. 13, No. 5, pp. 150-161.

Adamgbe, E. M., and Ujoh, F. (2013). "Effect of variability in rainfall characteristics on maize yield in Gboko, Nigeria," *Journal of Environmental Studies*, Vol. 4 No.9 pp 881-887.

Adejuwon, J.O., 2005. Food crop production in Nigeria. I. Present effects of climate variability. *Climate Research, 30*(1), pp.53-60.

Akpan, S. B., Inimfon, V. P., Samuel, J. U., Edem, A. O. and Uwemedimo, E. O. (2013). "Determinant of credit access and demand among poultry farmers in Akwa Ibom State, Nigeria," *American Journal of Experimental Agriculture*, Vol. 3 No. 2, pp. 293-307.

Amikuzuno, J. and Donkoh, S. A. (2012). "Climate variability and yields of major staple food crops in northern Ghana," *African Crop Science Journal,* Vol. 20 No. 2, pp. 349 – 360.

Ammann, C. M., Joos, F., Schimel, D. S., Otto-Bliesner, B. L. and Tomas, R. A. (2007). "Solar influence on climate during the past millennium: Results from transient simulations with the NCAR Climate System Model," *National Academy of Sciences,* Vol. 104 No. 10, pp. 3713–3718.

Anderson, K. and Bows, A. (2008). "Reframing the climate change challenge in light of post-2000 emission trends," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* Vol. 366 No.1882, pp. 3863–3882.

Antonakis, J. and Dietz, J. (2011). "Looking for validity or testing it? The perils of stepwise regression, extreme-scores analysis, heteroscedasticity, and measurement error", *Personality and Individual Differences*, Vol.50 No.3, pp.409-415.

Antwi-Agyei, P., Dougill, A. J., Fraser, E. D. and Stringer, L. C. (2013). "Characterising the nature of household vulnerability to climate variability: Empirical evidence from two regions of Ghana," *Environment, Development and Sustainability,* Vol.15 No.4, pp. 903-926.

Apusigah, A. A. (2009). "The gendered politics of farm household production and the shaping of women's livelihoods in Northern Ghana," *Feminist Africa,* Vol.12, pp 84-89

Arnell, N.W., Cannell, M.G., Hulme, M., Kovats, R.S., Mitchell, J.F., Nicholls, R.J., Parry, M.L., Livermore, M.T. and White, A. (2002). "The consequences of CO2 stabilisation for the impacts of climate change", *Climatic Change*, Vol.53 No.4, pp.413-446.

Asha, L. K. V., Gopinath, M. and Bhat, A. R. S. (2012). "Impact of climate change on rain-fed agriculture in India," *International Journal of Environmental Science and Development,"* Vol. 3 No. 4, pp.368-371.

Asante, F. A. and Amuakwa-Mensah, F. (2014). "Climate change and variability in Ghana: Stocktaking", *Climate*, Vol.3 No.1, pp.78-99.

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

Azman, E. A., Jusop, S., Ishak, C. F. and Ismail, R. (2014). "Increasing rice production using different lime sources on an acid sulphate soil in Merbok, Malaysia," *Pertanika Journal of Tropical Agricultural Science*, Vol.37 No.2, pp. 223-247.

Balance, D. (2011). "Assumptions in multiple regression: A tutorial" Available at www. Dianne balance portfolio. com/ uploads/ 1/2/8/2/.../ di_cv_july_2012. pdf (Accessed on 13 August 2014).

Barrett, C. B., Reardon, T. and Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications", *Food Policy,* Vol.26 No.4, pp. 315-331.

Basak, R. K. (2000), Soil Testing and Recommendation: A Text Book, Kalyani Publishers, Kolkata

Bationo, A. and Ntare, B. R. (2000). "Rotation and nitrogen fertilizer effects on pearl millet, cowpea and groundnut yield and soil chemical properties in sandy soil in the semi arid tropics, West Africa," *Journal of Agricultural Science,* Vol. 134, pp. 277-284.

Batterbury, S. P. J. (2004). "Development, planning, and agricultural knowledge on the Central Plateau of Burkina Faso," in Robson, E.and Cline-Cole, R. (Eds) *West African Worlds. Local and Regional Paths through 'Development', Modernity and Globalisation.* Pearson Education, New Jersey, pp. 259-279.

Batterbury, S. (2001). "Landscapes of diversity: a local political ecology of livelihood diversification in south-western Niger", *Cultural Geographies*, Vol.8 No.4, pp.437-464.

Beddington, J., Asaduzzaman, M., Clark, M., Fernandez, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Van Bo, N., Nobre, C. A., Scholes, R., Sharma, R., and Wakhungu, J. (2012). Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change. Copenhagen, Denmark. Available online at: http// www.ccafs. cgiar.org /commission (Accessed on 20 March 2013).

Boote, K. J., and Sinclair, T. R. (2006). "Crop physiology: Significant discoveries and our changing perspective on research," *Crop Science,* Vol. 46 No. 5, pp. 2270–2277.

Bradford, J. B., Lauenroth, K. W, Burke, C. I. and Paruelo, J. M. (2006). "The influence of climate, soils, weather, and land use on primary production and biomass seasonality in the United States Great Plains Ecosystems," *Springer,* Vol. 9 No.6, pp. 934–950 (doi: 10.1007/s10021-004-0164-1)

Brook, R. M. and Davila, J. D. (2000). "The peri-urban interface: A tale of two cities," Available at http://www.bartlett.ucl.ac.uk>dpu-books (Accessed on 3 January 2012)

Cabas, J., Weersink, A. and Olale, E. (2010). "Crop yield response to economic, site and climatic variables," *Journal of Climate Change,* Vol. 101 No. 3-4, pp. 599–616

Cabrera, V. E., Solis, D., Biagorria, G. A. and Leston, D. (2009). "Managing climate variability in agricultural analysis," in, Long, J. A. and Wells, D. S. (Eds.), *Ocean Circulation and El Nino: New Research Nova Science,* New York, NY, pp. 163-179.

Cardoso, A. O., Pinto, H. S., Dias, P. L., Ávila, A. M. H., Marin, F. R. and Pilau, F. (2010). "Extended time weather forecasts contributes to agricultural productivity estimates," *Theoretical and Applied Climatology,* Vol. 102 No. 3-4, pp. 343-350.

Chakraborty, K. and Mistri, B. (2015). "Soil fertility and its impact on agricultural productivity. A study in Sapar, Mouza, Burdwan-I C. D Block, West Bengal", *International Journal of Humanities and Social Science Studies,* Vol. 2 No. 3, pp.196-206.

Challinor, A. J., Wheeler, T.R., Garforth, C., Craufurd, P. and Kassam, A. (2007). "Assessing the vulnerability of food crop systems in Africa to climate change," *Climate Change,* Vol.83, No. 3, pp.381-399.

Challinor, A. J., Wheeler, T. R., Slingo, J. M., Craufurd, P. Q. and Grimes, D. I. F. (2004). "Design and optimisation of a large-area process-based model for annual crops," *Agricultural and Forest Meteorology,* Vol. 124 No. 1, pp. 99–120.

Challinor, A. J., Slingo J. M., Wheeler T. R., Craufurd P. Q. and Grimes, D. I. F. (2003). "Toward a combined seasonal weather and crop productivity forecasting system: Determination of the working spatial scale," *Journal of Applied Meteorology,* Vol. 42 No. 2, pp. 175-192.

Cheke, R. A. and Tratalos, J. A. (2007). "Migration, patchiness, and population processes illustrated by two migrant pests", *Bioscience,* Vol.57 No.2, pp.145-154.

Chijioke, O. A., Haile, M. and Waschkeit, C. (2011). "Implication of climate change on crop yield and food accessibility in Sub- Sarahan Africa," Available at www.zef.de/ file ad min /.../forum/.../2011Oyiga_Haile_Waschkeit.pd...(Accessed on 13 August 2013)

Christensen J. H, Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Koli, R. K, Kwon. W-T, Laprise. R, Rueda. V. M, Mearns. L, Menendez. C. G, Raisanen. J, Rinke. A., Sarr, A. and Wheton, P. (2007). "Regional climate projections." in: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (Eds) *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change.* Cambridge University Press, Cambridge, pp 847–940.

Church, J. A., White, N. J., and Arblaster, J. M. (2005). "Significant decadal-scale impact of volcanic eruptions on sea level and ocean heat content," *Nature*, Vol. 438 No.7064, pp. 74–77 (doi: 10.1038/nature04237).

Collier, P., Conway, G. and Venables, T. (2008). "Climate change and Africa," *Oxford Review of Economic Policy*, Vol.24 No.2, pp. 337–353.

Cooper, P. J. M., Rao, K. P. C., Singh, P., Dimes, J., Traore, P.S., Rao, K., Dixit, P. and Twomlow, S. (2009). "Farming with current and future climate risk: Advancing a 'hypothesis of hope' for rain-fed agriculture in the Semi-Arid Tropics," *Journal of Semi-Arid Tropical Agricultural Research*, Vol. 7, pp. 1-9.

Cutter, S. L., Mitchell, J. T. and Scott, M. S. (2000). "Revealing the vulnerability of people and places: A Case Study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, Vol. 90, pp. 713-737. http: // dx. doi. org/ 10. 1111/ 0004-5608. 00219

Davis, C. L. (2011). Climate Risk and Vulnerability: A Handbook for Southern Africa, Council for Scientific and Industrial Research, Pretoria, South Africa.

Daily Graphic Online (2015). "Flood disaster profile of Ghana since 1968", Available at www.graphic.com.gh> general news (Accessed on 26 October, 2015).

DeAngelis, A., Dominguez, F., Fan, Y., Robock, A., Kustu, M. and Robinson, D. (2010), "Observational evidence of enhanced precipitation due to irrigation over the Great Plains of the United States," *Journal of Geophysical Research*, Vol. 115 No. D15, pp 115-129.

Delworth, T. L., and Mann, M. E. (2000). "Observed and simulated multi-decadal variability in the Northern Hemisphere," *Climate Dynamics,* Vol.16 No.9, pp. 661–676.

Department For International Development (2004). "The impact of climate changes on the vulnerability of the poor: Climate change in Africa. Key Sheet Series number 10. Available at http://ncsp.va-network.org/ User /File /PDFs /Resource Center/ (Accessed on 3 July 2012).

Devereux, S. and Edwards, J. (2004). "Climate change and food security", *Institute of Development Studies Bulletin*, Vol. 35 No.3, pp.22-30.

Di Falco, S. and Chavas, J. P. (2009). "On crop biodiversity, risk exposure, and food security in the highlands of Ethiopia," *American Journal of Agricultural Economics*, Vol. 91 No.3, pp. 599-611.

Dias-Bioucas, J. M., Plaza, A., Dobigeon, N., Parente, M., Du, Q., Gader, P. and Chanussot, J. (2012). "Hyperspectral unmixing overview: Geometrical, statistical, and sparse regression-based approaches", *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Vol.5 No.2, pp. 354-379.

Díaz, S., and Cabido, M. **(**2001). "Plant functional diversity matters to ecosystem processes," *Trends in Ecology and Evolution,* Vol. 16 No. 11, pp. 646– 655.

Dietz, T., Millar, D., Dittoh, S., Obeng, F. and Ofori-Sarpong, E. (2004). "Climate and Livelihood Change in North East Ghana." in Dietz, A. J., Ruben, R. and Verhagen, A. (Eds), *The Impact of Climate Change on Drylands with a Focus on West Africa,* Kluwer Academic Publishers Dordrecht, Netherland, pp. 149- 172.

Dontwi, J., Dontwi, I. K. and Buabeng, S, N, (2008). "Climate change impacts on fisheries production" in Agyeman, B (Ed). *Ghana Climate Change Impacts, Vulnerability and Adaptation Assessment* Ghana . Environmental Protection Agency, pp. 14-55

Easterling, D. R., Meehl, G. A., Parmesan, C., Changnon, S. A., Karl, T. R. and Mearns, L. O. (2000), "Climate extremes: Observations, modeling, and impacts," *Science,* Vol. 289 No. 5487, pp. 2068–2074. (doi:10.1126/science.289.5487.2068).

Ebi, K. L., Mearns, L., O. and Nyenzi, B. (2005). "Weather and climate: Changing human exposures." in: McMichael, A. J., Campbell-Lendrum, D. H., Corvalan, C. F., Ebi, K. L, Githeko, A. (Eds). *Climate change and human health: Risks and responses,* World Health Organization, Geneva, pp. 18- 42

Ellis, F., (2000). *Rural livelihoods and diversity in developing countries*. Oxford university press.

Eakin, H. and Bojorquez-Tapia, L. A. (2008). "Insights into the composition of household vulnerability from multicriteria decision analysis", *Global Environmental Change* Vol.18 No.1, pp. 112-127.

Engels, S. and Van Geel, B. (2012). "The effects of changing solar activity on climate contribution from Palaeoclimatological studies", Journal of Space and Weather Space Climate Vol.2 A09, pp 1-9

Environmental Protection Agency (2008). "Ghana state of the environment report 2008," Environmental Protection Agency (EPA), Accra, Ghana. Available at https: //gh. linkedin. Com /in/ agnes adjabeng (Accessed on 6 November 2012).

Epstein, P. R. (2005). "Climate change and human health," *New England Journal of Medicine,* Vol. 353 No. 14, pp. 1433-1436.

Falloon, P. and Betts, R., (2010). "Climate impacts on European agriculture and water management in the context of adaptation and mitigation—the importance of an integrated approach", *Science of the Total Environment*, Vol.408 No.23, pp.5667-5687.

Fleshman, M. (2007), "Africa renewal climate change: Africa gets ready; planning how to deal with higher temperatures," *Shifting Weather,* Vol. 21 No.2, pp. 122-135.

Food and Agriculture Organization (FAO), (2008). "Climate change and food security: a framework document." Available at www.fao. org/forestry/ 15538-079b31d 45081 fe9c 3dbc6ff34d e4807e4. pdf (Accessed on 13 August 2013).

Food and Agriculture Organization, (2001). "Climate Change: Implications for Food Safety. FAO," Available at ftp://ftp.fao.org/docrep/fao/010/i0195e/i0195e00.pdf (Accessed on 13 August 2013).

Fosu-Mensah, Y. B. (2012). "Modeling maize (Zea mays L.) productivity and impact of climate change on yield and nutrient utilization in sub-humid Ghana," *Ecology and Development Series*, No. 87, pp, 12-129.

Gallopín, G. C. (2006). "Linkages between vulnerability, resilience, and adaptive capacity," *Global Environmental Change*, Vol. 16 No. 3, pp. 293-303.

Garrido, A., Bielza, M., Rey, D., Mınguez, M. I. and Ruiz-Ramos, M. (2011). "Insurance as an adaptation to climate variability in agriculture," in, Hazell, P., Mendelsohn, R and Dinar, A. (Eds.), *Handbook on Climate Change and Agriculture*, Edward Elgar, Cheltenham, UK, pp. 420–445.

Gbetibouo, G. A. and Ringler, C. (2009). "Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment." International Food Policy Research Institute (IFPRI) and Center for Environmental Economics and Policy in Africa (CEEPA).Discussion Paper 00885.

Geoff, C. (2004), "Climate change and bushfire incidence," in *Action for air in 2004 proceedings of the New South Wales' clean air forum,* Powerhouse Museum, Department of Environment and Conservation, Sydney, 17 November, 2004, pp. 15-18.

Ghana Statistical Service (2014). "Population and housing census: Summary report of final result." Available at www. Stats ghana. gov.gh/.../2010phc/ Census 2010 Summary report (Accessed on 13 August 2013).

Ghana Statistical Service (2010). "District analytical report: Bawku Municipality." Available at www. Stats ghana .gov.gh/ docfiles/2010... /Bawku%20 Municipality. Pdf (Acces sed on 13 August 2013).

Ghil, M. (2002). "Climate variability. The earth system: Physical and chemical dimensions of global environmental change", *Encyclopedia of Global Environmental Change,* Vol.1, pp. 544-549.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. and Wiltshire, A. (2010). "Implications of climate change for agricultural productivity in the early twenty-first century," *Philosophical Transaction of the Royal Society B,* Vol. 365 No. 1554, pp. 2972- 2989.

Grab, W. S. and Nash, D. J. (2010). "Documentary evidence of climate variability during cold seasons in Lesotho, southern Africa, 1833–1900," *Climate Dynamics,* Vol. 34 No. 4, pp. 473-499.

Gray, L. J., Beer, J., Geller, M., Haigh, J. D., Lockwood, M., Matthes, K., Cubasch, U., Fleitmann, D., Harrison, G., Hood, L. and Luterbacher, J. (2010). "Solar influences on climate", *Reviews of Geophysics*, Vol.48 No.4.

Guthiga, P. and Newsham, A. (2011). "Meteorologists meeting rainmakers: indigenous knowledge and climate policy processes in Kenya". *Institute of Development Studies Bulletin*, Vol.42 No.3, pp.104-109.

Hatfield, J. H., Boote, K. J., Kimball, B. A., Ziska, L. H., Izaurralde, R. C., Ort, D., Thomson, A. M. and Wolfe, D. W. (2011). "Climate impacts on agriculture: Implications for crop production," *Journal of Agronomics,* Vol.103, pp. 351–370

Herrero, M., Thornton, P. K. and Notenbaert, A. (2010). "Smart investments in sustainable food production: Revisiting mixed crop-livestock systems," *Science*, Vol. 327 No. 3 pp. 822–825.

Hochman, Z., Gobbett, D., Holzworth, D., McClelland, T., Rees, H.V., Marinoni, O., Garcia, J.N. and Horan, H. (2013). "Reprint of quantifying yield gaps in rain-fed cropping systems: A case study of wheat in Australia," *Field Crops Research,* Vol.143 pp. 65-75.

Hulme, M., Doherty, R. M., Ngara, T., New, M. G. and Lister, D. (2001). "African climate change: 1900–2100," *Climate Research*, Vol. 17, No. 2, pp. 145–168.

Hurrell, J. W (2003). "Hurrell North Atlantic Oscillation (NAO) P.C based". Available at http//www.climate data climate data guide acar. Edu /climate data/ hurrell north oscillation nao idex. p.c based (Accessed on 13 August 2013)

Intergovernmental Panel on Climate Change (IPCC) (2012). "Summary for policy makers," in, Field, C. B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi, K. L., Mastrandrea, M. D., Mach, K. J., Plattner, G. K., Allen, S. K., Tignor, M. and Midgley, P. M., (Eds.), *Managing the Risks of Extreme Events and Disasters to Adva- nce Climate Change Adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, pp. 1–19.

IPCC (2007). "Climate change 2007," in, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor M. and Miller H. L. (Eds.), *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 83-96.

IPCC (2001). "Climate change 2001," in McCarthy, J. J. (Ed.), *Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, UK, pp. 75-91.

Ismaila, U., Gana, A. S., Tswanya, N. M. and Dogara, D. (2010). "Cereals production in Nigeria: Problems, constraints, opportunities and betterment," *African Journal Agricultural Research,* Vol.5 No.12, pp. 1341-1350.

Janssen, M. A., Schoon, M. L., Ke, W. and Bo¨rner, K. (2006). "Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change," *Global Environment Change,* Vol. 16 No. 3, pp. 240–252.

Jennings, S. and Magrath, J. (2009). "What happened to the seasons?" Available at: http:// www. publications. oxfam.org.uk/display. asp.(Accessed on 13 August 2013).

Haigh, J. (2011). "Solar influence on climate". Available at https//www. imperial.ac.uk/… /solar-influence on climate---Grantham-BP pdf (Accessed on 13 August, 2013).

Kabat, P., Schulze, R. E., Hellmuth, M. E. and Veraart, J. A. (2002). "Coping with impacts of climate variability and climate change in water management: A scoping paper. Report No. 01, International Secretariat of the Dialogue on Water and Climate, Wageningen.

Kandji, S. T., Verchot, L. and Mackensen, J. (2006). "Climate change and variability in the Sahel region: Impacts and adaptation strategies in the agricultural sector", United Nations Environment Programme (UNEP) and World Agroforestry Centre (ICRAF), Nairobi, Kenya. Available at www. unep. org…/Themes /Freshwater/ .../Climate Change Sahel Combine. pdf (Accessed on 13 August, 2013).

Kandulu, J. M., Bryan, B. A., King, D. and Connor, J. D. (2012). "Mitigating economic risk from climate variability in rain-fed agriculture through enterprise mix diversification," *Ecological Economics,* Vol. 79, pp. 105-112.

Kasiulevičius, V., Šapoka V. and Filipavičiūtė R. (2006), "Sample size calculation in epidemiological studies" *Gerontologija,* Vol. 7 No.4, pp. 225–231

Kelbore, G. Z. (2011), "Climate change, crop yield variability, and food price volatility in Sub-Saharan Africa: The Ethiopian case," *Applied Economics*, Vol. 38, pp. 835-844.

Khan, S. A., Kumar, S., Hussain, M. Z. and Kalra, N. (2009). "Climate change, climate variability and Indian agriculture: Impacts vulnerability and adaptation strategies," in, Singh, S.N. (Ed.), *Environmental Science and Engineering,* 2009. Springer-Verlag Berlin Heidelberg, pp. 19-38.

Khantun, D. and Roy, B. C. (2012). "Rural livelihood diversification in West Bengal: Determinants and constraints," *Agricultural Economics Research Review,* Vol. 25 No. 1, pp. 115-124.

Kirsten, H., Hans, H. A., Henrik, L and Nethe, V. L. (2008). "Climate change screening of Danish Development Cooperation with Uganda." Final Report. Available at news. mak. ac.ug/ documents /RUFORUM/E kiyar. Doc (Accessed on 13 August 2013)

Klinsky, S. and Winkler, H. (2014), "Equity, sustainable development and climate policy," *Climate Policy,* Vol. 14 No.1, pp. 1-7, (DOI: 10.1080/14693062.2014.859352).

Kronlid, D. O. (2014), *Climate Change Adaptation and Human Capabilities: Justice and Ethics in Research and Policy.* Palgrave Macmillan. USA

Kumar, K. R., Ashrit, R. G., Deshpande, N. R. and Hansen, J. W. (2004). "Climate impacts on Indian agriculture," *International Journal of Climatology*, Vol. 24 No. 11, pp. 1375–93.

Kumar, S., Shukla, A. K. and Singh, H. V. (2013). "Intercropping of pearl millet and cowpea as rain-fed fodder crops," *International Interdisciplinary Research Journal*, Vol. 4, No. 3, pp.122-129

Kunstmann, H. and Jung, G. (2005). "Impact of regional climate change on water availability in the Volta basin of West Africa", *International Association of Hydrological Science* Vol.295, pp.75-85.

Lansigan, F. P., De Los Santos, W. L. and Coladilla, J. O. (2000). "Agronomic impacts of climate variability on rice production in the Philippines," *Agriculture, Ecosystems and Environment*, Vol. 82 No. 1, pp. 129-137.

Legler, D. M., Bryant, K. J. and O'Brien, J. J. (1999). "Impact of ENSO-related climate anomalies on crop yields in the US". *Climatic Change*, Vol.42 No.2, pp.351-375.

Li, J., Fan, Z., Bräuning, A., Thomas, A. and Cao, K. (2011). "Spatial and temporal temperature trends on the Yannan Plateau (Southwest China) during 1961-2004," *International Journal of Climatology*, Vol.31 No. 14, pp. 2078-2090.

Lipper, L., Dutilly-Diane, D., McCarthy, N. (2010). "Supplying carbon sequestration from West African rangelands: Opportunities and barriers," *Rangeland Ecology and Management*, Vol. 63 No.1, pp. 155-166.

Lobell, D. B., Schlenker W. and Costa-Roberts, J. (2011). "Climate trends and global crop production since 1980," *Science*, Vol. 333 No. 6042, pp. 616–620.

Ludi, E. (2009). "Climate change, water and food security." Background Note Overseas Development Institute.

Lyimo, J. G. and Kangalawe, R. Y. M. (2010). "Vulnerability and adaptive strategies to the impacts of climate change," *Environmental Economics*, Vol.1 No 2, pp.89-96.

Mackenzie, C., Rogers, W. and Dodds, S. (2014). Vulnerability: New essays in ethics and feminist philosophy. Oxford University Press, Oxford UK, pp 318.

Magrin, G., Trabaos, M. and Rodr´ıguez, G. (2005). "Changes in climate and crop production during the 20th century in Argentina," *Climatic Change*, Vol.72 No. 1–2, pp. 229–249.

Mantua, N. J. and Hare, S. R (2001). 'Pacific decadal oscillation,' *Journal of Oceanography*, Vol. 58 No. 1, pp. 34-44.

Maracchi, G., Sirotenko, O. and Bindi, M. (2005). "Impacts of present and future climate variability on agriculture and forestry in the temperate regions, *Europe. Climate Change* Vol.70 No1–2, pp.117–135.

Marsh, R., DeCuevas, B. A., Redbourn, L. J., Quartly, G. D. and Josey, S. A. (2005). "Recent warming of the North Atlantic and the role of ocean heat transport," *Journal of Geophysical Research*, Vol. 1, pp.127-144.

McCarl, B. A. (2006). "United States' agriculture in the climate change sequence." Available at texas climate.org /Portals/6/Books/ ImpactTX/Ch6 McCarl.pdf (Accessed on 20 April 2013).

McSweeney, C., Lizcano, G., New, M. and Lu, X. (2010). "The UNDP Climate Change Country Profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries", *Bulletin of the American Meteorological Society*, Vol.91 No.2, pp.157-166.

Met Office Hardley Centre (2011), "Global surface temperature." Available at www.met office. Gov .uk /research /monitoring /climate /surface-temperature (Accessed on 13 August 2013).

Meze-Hausken, E. (2004). "Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia," *Climate Research*, Vol. 27, pp. 19–31.

Mina, U. and Sinha, P. (2008). "Effects of climate change on plant pathogens," *Environmental News Letter*, Vol. 14 No. 4, pp 37-42.

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

Ministry of Food and Agricultural (2010). "A report on agricultural statistics": Statistics, research and information Directorate (SRID), Accra. Available at htpp:// www. ofa. gov. gh/site/ wp-content/ uploads/.../mofa_ facts_and_figures.pdf (Accessed on 6 November 2012).

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

Mortimore, M. J. and Adams, W. M. (2001). "Farmer adaptation, change and 'crisis' in the Sahel", *Global environmental change*, Vol.11No.1, pp.49-57.

Mowa, E. L and Lambi, C. M. (2006). "Economic impact ofclimate change on agriculture in Cameron. *Policy research paper* No. 4364 World Bank, Washington, D.C. pp. 51-55.

Mudombi-Rusinamhodzi, G., Siziba, S. and Kongo, V. (2012). "Factors affecting small holder farmers responsiveness to climate variability induced hazards in Zimbabwe," African *Crop Science Journal*, Vol. 20 No. 2, pp. 297-301.

National Aeronautics and Space Administration (NASA) (2011). "Climate change: Vital signs of the planet." Available at www. climate. nasa. gov>news (Accessed on 13 Aug 2013).

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. and Kaltenborn, B. (2009). "The environmental food crisis: The environment's role in averting future food crises." A UNEP rapid response assessment. Arendal, UNDP, Nelson, G. C., Rosegrant, W. M., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S. and You, L. (2010). “Food security, farming, and climate change to 2050: Scenarios, results, policy options.” Washington, D.C.: International food policy research institute. Available at http://www.ifpri.org /sites/default/ files/publications/ ib66.pdf/(Accessed on 13 Aug 2013).

Newman J. A. (2004).” Climate change and cereal aphids: the relative effects of increasing CO_2 and temperature on aphid population dynamics”, *Global Change Biology.* Vol.10, pp.5–15.

Nguyen, N. V. (2006). “Global climate changes and rice food security.” FAO, Rome Available at http://wwwfao.org/climatechange/ 1552603ecb62366 f779d1ed 45287 e698a 442e.pdf (Accessed 13 August 2013).

Nikoi, A. R. (2010). *Human Geography for Senior High Schools.* Aki Ola Publications. Accra, Ghana.

Nyantakyi-Frimpong, H. (2013). “Indigenous knowledge and climate adaptation policy in Northern Ghana.” A project of the Africa initiative backgrounder No 48 January 2013.

O’Brien, K. Leichenko, L., Kelkar, U., Venema, H., Andahl, G., Toompkins, H., Javed, A., Bhadwal, S., Brag, S., Nygaard, L. and West, J. (2004). “Mapping vulnerability to multiple stressors: Climate change and economic globalization in India,” *Global Environmental Change,* Vol. 14 No.4, pp. 303-313.

Ochieng, J., Owuor, G. and Bebe, B. O. (2012). “Determinants of adoption of management interventions in indigenous chicken production in Kenya”, *African Journal of Agricultural and Resource Economics*, Vol.7 No.1, pp.39-50.

Okali, D. (2011). “Climate change and Africa moist forest,” in, Chidumayo, E., Okali, D., Kowero, G. and Larwanou, M. (Eds), *Climate Change and African Forest and Wildlife Resources,* African Forestry Forum, Nairobi, Kenya, pp. 68-84.

Olesen, J. E., Carter, T. R., Diaz-Ambrona, C. H., Fronzek, S., Heidmann, T., Hickler, T., Holt, T., Minguez, M. I., Morales, P., Palutikof, J., Quemada, M., Ruiz-Ramos, M., Rubik, G., Sau, F., Smith, B., Sykes, M. (2007). “Uncertainties in projected impacts of climate change on European agriculture and terrestrial ecosystems based on scenarios from regional climate models”, *Climatic Change*, Vol.81, pp. 123-143

Olmos, S. (2001). “Vulnerability and adaptation to climate change: Concepts, issues, assessment methods climate change knowledge,” Network Foundation Paper. Available at http:// www. cckn. net/ (Accessed on 16 August 2013).

Olsen, C. and George, D. M. M. (2004). “Cross sectional study design and data analysis.” Available at www. college board. com/ prod_ downloads / yes/ 4297 _ MO DULE 05. pdf (Accessed on 23 February 2012).

Onoja, A. and Ajie, E. N. (2012). “Econometric analysis of food crops’ response to climate variability and macroeconomic policies reforms in Nigeria (1978- 2009),” *Asian Journal of Agriculture and Rural Development*, Vol.2 No, 3, pp. 487-497.

Oppenheimer, C. (2003). “Climatic, environmental and human consequences of the largest known historic eruption: Tambora volcano (Indonesia) 1815”, *Progress in physical geography*, Vol.27 No.2, pp.230-259.

Oppong-Anane, K. (2006). “Country pasture/forage resources profiles: Ghana. Food and Agriculture Organization of the United Nations (FAO)”. Available at http://www. fao.org/ag/AGP /AGPC /doc /Counprof /PDF%20files/Ghana-English.pdf (Accessed 2 Apri, 2012).

Oppong-Ansah, A. (2011). “Getting the fight against floods right in Ghana,” Available at http://www. ghana/ news agency.org/ (Accessed on 3 July 2012).

Oremo, F. O. (2013). “Small-scale farmers’ perceptions and adaptation measures to climate change in Kitui county, Kenya.” Available at www. erepository. uonbi. ac. ke (Accessed on 20 April 2014).

Osborne, T. M. and Wheeler, T. R. (2013). “Evidence for a climate signal in trends of global crop yield variability over the past 50 years,” *Environmental Research Letters*, Vol.8 No.2,pp. 1-9

Owusu, K. and Waylen, P. (2009). “Trends in spatio-temporal variability in annual rainfall in Ghana (1951-2000),” *Weather,* Vol.64 No.5, pp.115-120.

Pan, Z., Yang, X. B., Pivonia, S., Xue, L., Pasken, R., and Roads, J. (2006). “Long-term prediction of soybean rust entry into the continental United States,” *Plant Disease,* Vol. 90 No. 7, pp. 840-846.

Paeth, H., Fink, A. H., Pohl, S., Keis, F., Machel, H. and Samimi, C. (2011). “Meteorological characteristics and potential causes of the 2007 flood in sub-Saharan Africa”, International Journal of Climatology, Vol. 31 No. 13, pp. 1908-1926.

Parry, M., Evans, A., Rosegrant, M. W. and Wheeler, T. (2009). “Climate change and hunger: Responding to the challenge. Rome World Food Programme, Available at http// www. wfp.org/stellent/groups/public/documents/wfp212536.pdf (accessed on 13 August 2013).

Peprah, K. (2014). “Rainfall and temperature correlation with crop yield: The case of Asunafo forest, Ghana,” *International Journal of Science and Research,* Vol. 3 No. 5, pp. 784-789.

Porter, J. R. and Semenov, M. A. (2005). “Crop responses to climatic variation,” *Philosophical Transactions of the Royal Society B: Biological Sciences,* Vol. 360 No, 1463, pp. 2021–2038.

Preston, I., Blundell, R.W., and Walker, I. (1994). *The measurement of household welfare*. Cambridge University Press.

Ramadoss, M., Birch, C. J., Carberry, P. S. and Robertson, M. (2004, September).“Water and high temperature stress effects on maize production,” in, *Proceedings of the 4th International Crop Science Congress,* 26 September 2004 to1 October 2004,Brisbane, Australia. Available at www.cropscience.org.au (Accessed on 13 August 2013).

Reynolds, M. P. and Ortiz, R. (2010). “Adapting crops to climate change; a summary: Climate change and crop production,” CAB international, Oxfordshire, U.K, pp.1-8.

Rickards, L. and Howden, S. M. (2012). “Transformational adaptation: Agriculture and climate change,” *Crop and Pasture Science,* Vol. 63 No. 3, pp. 240-250.

Robeyns, I. (2005). “The capability approach: a theoretical survey”, *Journal of human development*, Vol.6 No.1, pp.93-117.

Roncoli, C., Ingram, K. and Kirshen, P. (2002). “Reading the rains: local knowledge and rainfall forecasting in Burkina Faso”, *Society and Natural Resources*, Vol.15 No.5, pp.409-427.

Rosenzweig, C., Casassa, G. and Karoly, D. J. (2007). “Assessment of observed changes and responses in natural and managed systems,” in, Parry, M. L., Canziani, O. F., Palutikof, J.P., and Van der Linden, P. J. (Eds), *Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge: Cambridge University Press, pp. 79–131.

Rosenzweig, C., Tubiello, F. N., Goldberg, R., Mills, E. and Bloomfield, J. (2001). “Increased crop damage in the United States from excess precipitation under climate change,” *Global Environmental Change: Human Dimensions and Policy,*Vol.12 No.3, pp. 197-202.

Rowhani, P., Lobell, D. B., Linderman, M. and Ramankutty, N. (2011). “Climate variability and crop production in Tanzania,” *Agricultural and Forest Meteorology,* Vol. 51, pp.449–460.

Roy, D. and Venema, H. D. (2009). “Climate change and gender justice.” Available at www. Climate access.org/.../Terry_Climate% 20Change%20and%20 Gender. (Accessed on 10 April, 2014).

Ruijs, A., Bell, M. D., Kononen, M., Linderhof, V. and Polman, N. (2010). “Adaptation to climate variability: The role of past experience and institutions,” in Governance and Economics Adaptation proceedings of international conference in Rotterdam, 29 September to 1 October 2010 pp. 173-174. Available at www. Climate delta conference.org/.../DELTAS % 20 ABSTRACTS %200909 (Accessed on 13 August 2013).

Sallu, S..M., Twyman, C. and Stringer, L. C. (2010). “Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Bostwana,” *Ecology and Society,* Vol. 16 No. 3, pp. 3-16.

Sand, I. (2012). “Assessing vulnerability to climate variability and change participatory assessment approach, Kenyan case study,” Bonn: German Development Institute, Germany.

Sandelowski, M. (2000). “Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies,” *Research in Nursing and Health*, Vol. 23, pp. 246–255.

Schlecht, E., Buerkert, A., Tielkes, E. and Bationo, A. (2006). “A critical analysis of challenges and opportunities for soil fertility restoration in Sudan-Sahel West Africa,” *Nutrient Cycling in Agroecosystem*, Vol. 76, pp. 109–136.

Schlenker, W. and Lobell, D. (2010). “Robust negative impacts of climate change of African agriculture,” *Environment Research Letters*, Vol. 5 No. 1, pp. 1-8.

Schmidhuber, J. and Tubiello, F. N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences*, Vol.104 No.50, pp.19703-19708.

Scoones, I. (2009). “Livelihoods perspectives and rural development,” *The Journal of Peasant Studies*, Vol. 36 No. 1, pp. 171-196.

Scott, L. (2008). “Climate variability and climate change: Implications for chronic poverty,” No 108, working paper, Overseas Development Institute.

Sen, A., (1999). “Commodities and capabilities”. Oxford University Press Catalogue. Available at www. https: //global. oup. com/ academic/ ... /commodities- and-capabilities- 9780195650389 (Accessed on 19April 2012).

Shakoor, U., Saboor, A., Baig, I., Afzal, A. and Rahman, A. (2015), “Climate variability impacts on rice crop production in Pakistan,” *Pakistan Journal of Agricultural Research*, Vol. 28 No.1, pp.19-27.

Shaviv, N. and Veizer, J. **(**2003). “Celestial driver of phanerozoic climate,” *Geological Society America*, Vol. 13 No. 7, pp. 4-10.

Siegenthaler, U., Stocker, T. and Monnin, E. (2005). “Stable carbon cycle–climate relationship during the late Pleistocene,” *Science*, Vol. 310 No. 5752, pp. 1313–1317.

Simbarashe, G. (2013). “Climate change, variability and sustainable agriculture in Zimbabwe’s rural communities,” *Russian Journal of Agricultural and Socio-Economic Sciences*, Vol.2 No. 14, pp. 89-100.

Sivakumar M. V. K., Das H. P. and Brunini, O. (2005). “Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics”, *Climate Change* Vol.70, pp.31–72.

Sivakumar, M. V. K., Gommes, R., and Baier, W. (2000). “Agrometeorology and sustainable agriculture,” *Agricultural and Forest Meteorology*, Vol.103 No.1, pp.11-26.

Slater, R., Peskett, L., Ludi, E. and Brown, D. (2007). ‘Climate change, agricultural policy and poverty reduction – how much do we know?’, *Natural Resource Perspectives,* 109.

Smit, B., and Wandel, J. (2006). “Adaptation, adaptive capacity and vulnerability,” *Global Environmental Change,* Vol.6 No.3, pp.282-292.

Spahni, R., Chappellaz, J., Stocker, T. F., Loulergue, L., Hausammann, G., Kawamura, K. and Flückiger, J. (2005). “Atmospheric methane and nitrous oxide of the late Pleistocene from Antarctic ice cores,” *Science*, Vol. 310 No. 5752, pp.1317–1321.

Stanturf, A. J., Warren, M. L. J., Charnley, S., Polasky, S. C., Goodrick, S. L., Armah, F. and Nyako, Y. A. (2011). “Ghana climate change vulnerability and adaptation assessment.” Available at http: //www. encapafrica. org/documents/ biofor/Climate 20 % Change 20% Assessment _Ghana_20% FINAL.pdf (Accessed on 3 July 2012).

Stott, P. A., Gillett, N. P., Hegerl, G. C., Karoly, D. J., Stone, D. A., Zhang, X. and Zwiers, F. (2011). “Detection and attribution of climate change: A regional perspective,” *Wiley Interdisciplinary Reviews: Climate Change,* Vol.1 No.2, pp.192-211.

Sun, F., Roderick, M. L. and Farquhar, D. G. (2012). “Changes in the variability of global land precipitation,” *Geophysical Research Letters,* Vol.39 No. 19, pp. 1-6.

Tesso, G., Emana, B. and Ketema, M. (2012). “A time series analysis of climate variability and its impacts on food production in Northern Shewa Zone in Ethiopia,” *Africa Crop Science,* Vol. 20 No.2, pp. 261-274.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G. and Rockström, J. (2006). Reducing hazard vulnerability: Towards a common approach between disaster risk reduction and climate adaptation. *Disasters,* Vol. 30 No.1, pp.39-48.

Thornton, P. K., Ericksen, P. J., Herrero, M. and Challinor, A. J. (2014). “Climate variability and vulnerability to climate change: A review”, *Global Change Biology,* Vol.20 No.11, pp. 3313-3328.

Thornton, P. K. and Lipper, L. (2013). “How does climate change alter agricultural strategies to support food security?” Background paper for the conference “Food Security Futures: Research Priorities for the 21st Century”, 12 April 2013, Dublin. pp. 11-12. Available at http:// www. pim .cgiar. org/ files/ 2013/03/ Climate Change And Food Security_Priorities For. pdf. (Accessed on 13 August 2013).

Thornton, P.K., Jones, P.G., Alagarswamy, G., Andresen, J. and Herrero, M., (2010). “Adapting to climate change: agricultural system and household impacts in East Africa”. *Agricultural systems,* Vol. 103 No.2, pp.73-82.

Tonah, S. (2006), “Migration and farmer-herder conflicts in Ghana’s Volta Basin,” *Canadian Journal of African Studies,* Vol.40 No.1, pp.152-178.

Trenberth, K. E., Jones, P. D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A., Parker, D. Rahimzadeh, F., Renwick, J. A., Rusticucci, M., Soden, B. and Zhai, P. (2007). "Observations: Surface and atmospheric climate change," in Solomon, S., Qin, D..Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (Eds.). Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 237-336.

Tubiello, F. and Fischer, G. (2006). "Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000–2080," *Technology of Forecasting Social. Change,* Vol 74 No. 7, pp.1030–1056 (doi:10.1016/j.techfore.2006.05.027).

Tubiello, F. N., Soussana, J. F. and Howden, S. M. (2007). "Crop and pasture response to climate change," *National Academic of Science,* Vol. 104, No. 50, pp. 19686–19690.

Tubiello, F.N., Donatelli, M., Rosenzweig, C. and Stockle, C.O., (2000). "Effects of climate change and elevated CO 2 on cropping systems: Model predictions at two Italian locations". *European Journal of Agronomy,* Vol.13 No. 2, pp.179-189.

Tuck G., Glendining M. J., Smith P., House J. I., Wattenbach, M. (2006). "The potential distribution of bioenergy crops in Europe under present and future climate". *Biomass Bioenergy* Vol. 30, pp. 183–197.

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

Tunde, A. M., Usman, B. A. and Olawepo, V. O. (2011). "Effects of climatic variables on crop production," *Journal of Geography and Regional Planning,* Vol. 4 No. 14, pp. 708-714.

United Nation Framework Convention on Climate Change (UNFCCC) (2011). "Reducing vulnerability to climate change, climate variability and extremes, land degradation and loss of biodiversity: Environmental and developmental challenges and opportunities." Available at unfccc. Int / resource/ docs /publications/ ldcreducing vulnerability. Pdf (Accessed on 13 August 2013).

United Nations Development Programme (UNDP) (2007). "Fighting climate change: human solidarity in a divided world". Human Development Report 2007/2008. Available at www.hdr.undp.org/.../reports/.../hdr...(Accessed on 3 July 2012).

Van de Steeg, J. A., Herrero, M., Kinyangi, J., Thornton, P. K., Rao, K. P. C., Stern, R. and Cooper, P. (2009). "The influence of climate variability and climate change on the agricultural sector in East and Central Africa. Sensitizing the ASARECA strategic plan to climate change," *ILRI Research Report* 22. Nairobi, Kenya: Available at www. asareca.org/ sites/ default/ files/ Climate_Change_Report.pdf (Accessed on 13 August 2013).

Van Asten, P. J. A., (2003). "Soil Quality and rice productivity problems in Sahelian irrigation schemes. Ph.D. Thesis. Wageningen University, ISBN 90-5808-852-9, Wageningen, The Netherlands, pp.143

Vermeulen, J. S., Campbell, B. M. and Ingram, J. S. I. (2012). "Climate change and food systems," *Annual Review of Environment and Resources*, Vol. 37, pp. 195-222 (doi:10.1146/020411-130608).

Vidal, J. (2009). "Rich nations failing to meet climate aid pledges," The Guardian, 20 February pp. 1, 3-4.

Walther S. and Abtew W.(2006) Contribution of rainfall from tropical systems in South Florida. In South Florida Water Management District, West Palm Beach. Palm Beach, FL: Environmental Resources Department.

Wanner, H., Bronnimanns, S., Casty, C., Gyalistras, D., Lusterbacher, J., Schmutiz, C., Stephenson, D. B. and Xoplaki, E. (2001). North Atlantic Oscillations: Concepts and studies,' *Survey in Geophysics,* Vol. 22, pp. 321-382.

Watts, A. (2012). "Global precipitation variability decreased from 1940 to 2009." Available at wattsup with that. com/2012/.../global-precipitation-variability-from-1940 (Accessed on 13 August 2013).

Welch, J. R., Vincent, J. R., Auffhammer, M. Moya, P. F., Dobermann, A. and Dawe, D. (2010). "Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures," *Proceedings of National. Academy of Science,* 107 (2010), pp. 14562–14567.

Wood, T. N. (2013). "Agricultural Development in the Northern Savannah of Ghana," D.P.H. Doctoral Document, University of Nebraska, Lincoln. Available at http//digital commons. un. Edu / plant health doc. (Accessed on 20 April 2013)

World Climate Report (2012). "Agriculture: Tropical cyclones are welcome visitors." Available at www. world climate report.com/ (Accessed on 13 August 2013).

World Meteorological Organisation (2001). Weather climate and food security-Integrated drought. management. Available at www.droughtmanagement. info/... /WMO_ weather_climate_ food_security_2001.pdf (Accessed on 18 January 2012)

Yeasmin, S. and Rahman, K. F. (2012). "Triangulation research method as the tool of social science research," *Bangladesh University of Professionals (BUP) Journal,* Vol. 1 No. 1, pp. 154-163.

Yeboah, M. A. (2008). "Gender and livelihoods: Mapping the economic strategies of porters in Accra, Ghana." Available at www. https: //books. google. com/ books? isbn= 0549787429 (Accessed on 13 August 2013).

Yiran, G. A. B., Kusimi, J. M., and Kufugbe, S. K. (2012). "A synthesis of remote sensing and local knowledge approaches in assessing land degradation in the Bawku East district-Ghana," *International Journal of Applied Earth Observation and Geoinformation*, Vol.14 No 1, pp. 204-213.

Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortés, S., and Downing, T. (2006). "Climate variability and change: Implications for household food security." AIACC Working Paper No. 20 January 2006, pp.

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

APPENDICES
APPENDIX I

Correlations

		Average temperature	Rainfall	Maize	Rice	Millet	Soil pH	Organic matter	Phosphorus	Nitrogen
Average Temperature	Pearson Correlation	1	-.156	-.123	.029	.314	.083	.110	-.248	.225
	Sig. (2-tailed)		.578	.661	.917	.255	.769	.696	.374	.419
	N	15	15	15	15	15	15	15	15	15
Rainfall	Pearson Correlation	-.156	1	.741**	.670**	-.070	.496	.366	.583*	.305
	Sig. (2-tailed)	.578		.002	.006	.805	.060	.180	.022	.268
	N	15	15	15	15	15	15	15	15	15
Maize	Pearson Correlation	-.123	.741**	1	.653**	-.012	.542*	.555*	.550*	.548*
	Sig. (2-tailed)	.661	.002		.008	.966	.037	.032	.034	.034
	N	15	15	15	15	15	15	15	15	15
Rice	Pearson Correlation	.029	.670**	.653**	1	.134	.733**	.638*	.521*	.707**
	Sig. (2-tailed)	.917	.006	.008		.633	.002	.011	.047	.003
	N	15	15	15	15	15	15	15	15	15
Millet	Pearson Correlation	.314	-.070	-.012	.134	1	.414	.466	-.025	.279
	Sig. (2-tailed)	.255	.805	.966	.633		.125	.080	.930	.314
	N	15	15	15	15	15	15	15	15	15
Soil pH	Pearson Correlation	.083	.496	.542*	.733**	.414	1	.900**	.400	.800**
	Sig. (2-tailed)	.769	.060	.037	.002	.125		.000	.139	.000
	N	15	15	15	15	15	15	15	15	15
Organic Matter	Pearson Correlation	.110	.366	.555*	.638*	.466	.900**	1	.111	.900**
	Sig. (2-tailed)	.696	.180	.032	.011	.080	.000		.695	.000
	N	15	15	15	15	15	15	15	15	15
Phosphorus	Pearson Correlation	-.248	.583*	.550*	.521*	-.025	.400	.111	1	.016
	Sig. (2-tailed)	.374	.022	.034	.047	.930	.139	.695		.956
	N	15	15	15	15	15	15	15	15	15
Nitrogen	Pearson Correlation	.225	.305	.548*	.707**	.279	.800**	.900**	.016	1
	Sig. (2-tailed)	.419	.268	.034	.003	.314	.000	.000	.956	
	N	15	15	15	15	15	15	15	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX II

Multiple regression analysis of climate variables on food crop production

A. Dependent Variable: LNRICE

Method: Least Squares
Date: 04/21/15 Time: 09:20
Sample: 1999 2013
Included observations: 15
LNRICE=C(1)+C(2)*LNAVERAGE_TEM+C(3)*LNRAINFALL+C(4)
*LNSOIL_PH

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-7.619448	21.26389	-0.358328	0.7269
C(2)	1.077336	6.335283	0.170053	0.8681
C(3)	0.323560	0.232461	1.391894	0.1915
C(4)	6.644933	2.564687	2.590934	0.0251

R-squared	0.583894	Mean dependent var	9.854978
Adjusted R-squared	0.470411	S.D. dependent var	0.495878
S.E. of regression	0.360865	Akaike info criterion	1.022553
Sum squared resid	1.432459	Schwarz criterion	1.211366
Log likelihood	-3.669145	Hannan-Quinn criter.	1.020541
F-statistic	5.145193	Durbin-Watson stat	1.213594
Prob(F-statistic)	0.018263		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.428553	Prob. F(1,10)	0.5275
Obs*R-squared	0.616413	Prob. Chi-Square(1)	0.4324

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/21/15 Time: 09:31
Sample: 1999 2013
Included observations: 15
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.321485	21.93181	-0.060254	0.9531
C(2)	0.086292	0.272717	0.316417	0.7582
C(3)	0.176617	6.512135	0.027121	0.9789
C(4)	0.072760	2.636361	0.027599	0.9785
RESID(-1)	0.347985	0.531568	0.654640	0.5275

R-squared	0.041094	Mean dependent var	-1.30E-15
Adjusted R-squared	-0.342468	S.D. dependent var	0.319873
S.E. of regression	0.370620	Akaike info criterion	1.113924

Sum squared resid	1.373593	Schwarz criterion	1.349940
Log likelihood	-3.354427	Hannan-Quinn criter.	1.111409
F-statistic	0.107138	Durbin-Watson stat	1.492655
Prob(F-statistic)	0.977319		

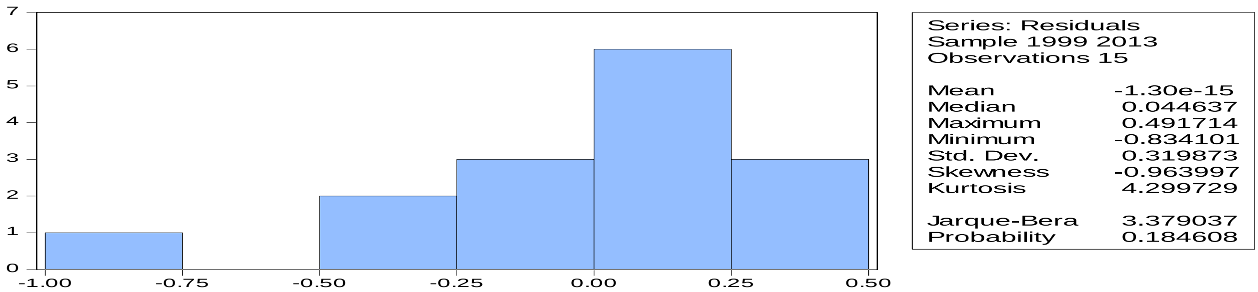
Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.038952	Prob. F(3,11)	0.4134
Obs*R-squared	3.311844	Prob. Chi-Square(3)	0.3460
Scaled explained SS	2.938469	Prob. Chi-Square(3)	0.4012

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/21/15 Time: 09:43
Sample: 1999 2013
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.367200	10.53670	0.604288	0.5579
LNRAINFALL	0.125023	0.115189	1.085373	0.3010
LNAVERAGE_TEM	-1.046472	3.139265	-0.333349	0.7451
LNSOIL_PH	-2.044754	1.270856	-1.608958	0.1359

R-squared	0.220790	Mean dependent var	0.095497
Adjusted R-squared	0.008278	S.D. dependent var	0.179561
S.E. of regression	0.178816	Akaike info criterion	-0.381739
Sum squared resid	0.351727	Schwarz criterion	-0.192925
Log likelihood	6.863041	Hannan-Quinn criter.	-0.383750
F-statistic	1.038952	Durbin-Watson stat	1.575830
Prob(F-statistic)	0.413418		



B. Dependent Variable: LNMAIZE
Method: Least Squares
Date: 04/21/15 Time: 09:55
Sample: 1999 2013
Included observations: 15
LNMAIZE=C(1)+C(2)*LNAVERAGE_TEM+C(3)*LNRAINFALL+C(4)
*LNORGANIC_MATTER

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	27.67440	28.20512	0.981184	0.3476
C(2)	-3.913351	8.010983	-0.488498	0.6348
C(3)	0.668053	0.271932	2.456692	0.0319
C(4)	1.872949	0.777664	2.408429	0.0347

R-squared	0.609131	Mean dependent var	9.967969
Adjusted R-squared	0.502531	S.D. dependent var	0.645136
S.E. of regression	0.455024	Akaike info criterion	1.486245
Sum squared resid	2.277515	Schwarz criterion	1.675059
Log likelihood	-7.146839	Hannan-Quinn criter.	1.484234
F-statistic	5.714145	Durbin-Watson stat	1.652815
Prob(F-statistic)	0.013159		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.058273	Prob. F(1,10)	0.8141
Obs*R-squared	0.086904	Prob. Chi-Square(1)	0.7682

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/21/15 Time: 09:56
Sample: 1999 2013
Included observations: 15
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-3.065800	32.11394	-0.095466	0.9258
C(2)	1.105583	9.547771	0.115795	0.9101
C(3)	-0.027750	0.306733	-0.090469	0.9297
C(4)	0.097729	0.908451	0.107578	0.9165
RESID(-1)	0.114982	0.476316	0.241399	0.8141

R-squared	0.005794	Mean dependent var	1.41E-15
Adjusted R-squared	-0.391889	S.D. dependent var	0.403336
S.E. of regression	0.475849	Akaike info criterion	1.613768
Sum squared resid	2.264320	Schwarz criterion	1.849785
Log likelihood	-7.103261	Hannan-Quinn criter.	1.611254
F-statistic	0.014568	Durbin-Watson stat	1.664698
Prob(F-statistic)	0.999504		

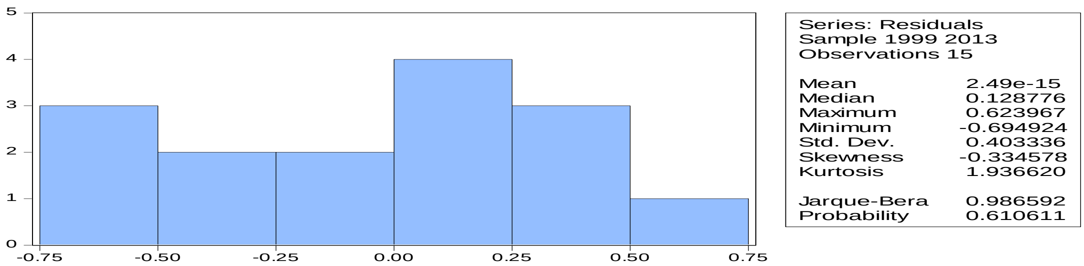
Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.561979	Prob. F(3,11)	0.2541
Obs*R-squared	4.481024	Prob. Chi-Square(3)	0.2140
Scaled explained SS	1.128531	Prob. Chi-Square(3)	0.7702

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/21/15 Time: 09:56
Sample: 1999 2013
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.385953	8.907088	-0.267871	0.7938
LNAVERAGE_TEM	0.045115	2.529843	0.017833	0.9861
LNRAINFALL	-0.003778	0.085875	-0.043992	0.9657
LNORGANIC_MATTER	-0.499823	0.245584	-2.035245	0.0666

R-squared	0.298735	Mean dependent var	0.151834
Adjusted R-squared	0.107481	S.D. dependent var	0.152101
S.E. of regression	0.143695	Akaike info criterion	-0.819067
Sum squared resid	0.227131	Schwarz criterion	-0.630254
Log likelihood	10.14300	Hannan-Quinn criter.	-0.821078
F-statistic	1.561979	Durbin-Watson stat	1.167606
Prob(F-statistic)	0.254071		



C. Dependent Variable: LNMILLET
Method: Least Squares
Date: 04/21/15 Time: 10:00
Sample: 1999 2013
Included observations: 15
LNMILLET=C(1)+C(2)*LNAVERAGE_TEM+C(3)*LNRAINFALL
+C(4)
*LNORGANIC_MATTER

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-5.155400	31.74246	-0.162413	0.8739
C(2)	8.268311	9.015681	0.917103	0.3788
C(3)	-0.043149	0.306036	-0.140992	0.8904
C(4)	2.595624	0.875195	2.965767	0.0128

R-squared	0.505969	Mean dependent var	9.841667
Adjusted R-squared	0.371234	S.D. dependent var	0.645807
S.E. of regression	0.512091	Akaike info criterion	1.722549
Sum squared resid	2.884607	Schwarz criterion	1.911362
Log likelihood	-8.919118	Hannan-Quinn criter.	1.720538
F-statistic	3.755276	Durbin-Watson stat	2.343561
Prob(F-statistic)	0.044466		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.550051	Prob. F(1,10)	0.2415
Obs*R-squared	2.013044	Prob. Chi-Square(1)	0.1560

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/21/15 Time: 10:00
Sample: 1999 2013
Included observations: 15
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-27.18030	37.89735	-0.717208	0.4897
C(2)	7.434285	10.63332	0.699150	0.5004
C(3)	-0.010818	0.298787	-0.036208	0.9718
C(4)	-0.470545	0.933986	-0.503803	0.6253
RESID(-1)	-0.508576	0.408492	-1.245010	0.2415

R-squared	0.134203	Mean dependent var	-3.63E-16
Adjusted R-squared	-0.212116	S.D. dependent var	0.453920
S.E. of regression	0.499748	Akaike info criterion	1.711778
Sum squared resid	2.497485	Schwarz criterion	1.947794
Log likelihood	-7.838332	Hannan-Quinn criter.	1.709264
F-statistic	0.387513	Durbin-Watson stat	2.084274
Prob(F-statistic)	0.812944		

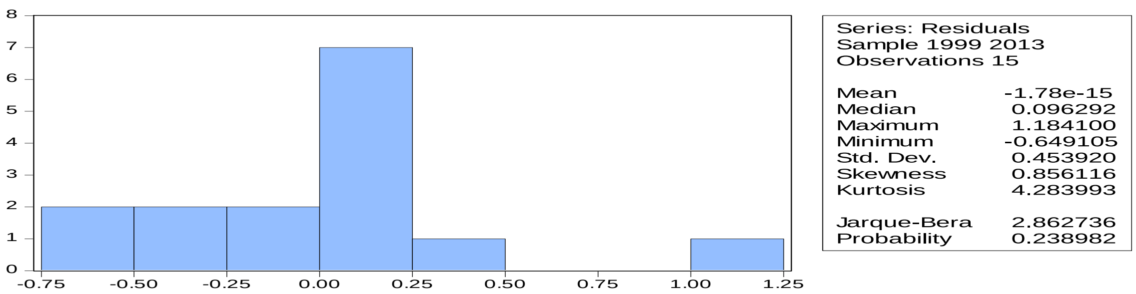
Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	2.322452	Prob. F(3,11)	0.1314
Obs*R-squared	5.816678	Prob. Chi-Square(3)	0.1209
Scaled explained SS	5.136297	Prob. Chi-Square(3)	0.1621

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/21/15 Time: 10:01
Sample: 1999 2013
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.870247	19.73757	-0.196085	0.8481
LNAVERAGE_TEM	1.520712	5.605981	0.271266	0.7912
LNRAINFALL	-0.418308	0.190294	-2.198216	0.0502
LNORGANIC_MATTER	-0.364907	0.544199	-0.670540	0.5163

R-squared	0.387779	Mean dependent var	0.192307
Adjusted R-squared	0.220809	S.D. dependent var	0.360727
S.E. of regression	0.318420	Akaike info criterion	0.772287
Sum squared resid	1.115303	Schwarz criterion	0.961100
Log likelihood	-1.792149	Hannan-Quinn criter.	0.770275
F-statistic	2.322452	Durbin-Watson stat	2.283391
Prob(F-statistic)	0.131420		



Appendix III

A Soil fertility in the Bawku Municipality for the Year 1999-2013

Year	Soil Ph 2:1 water/soil	Organic Matter %	Nitrogen %	Available Phosphorus mg/kg
1999	6.30	1.12	0.05	6.75
2000	6.20	1.10	0.04	6.45
2001	6.00	0.88	0.04	6.22
2002	6.10	0.85	0.03	8.93
2003	5.80	0.78	0.03	7.50
2004	5.90	0.80	0.03	7.80
2005	5.70	0.78	0.03	6.06
2006	5.80	0.81	0.03	6.23
2007	5.70	0.79	0.03	7.21
2008	5.60	0.75	0.03	5.74
2009	5.70	0.76	0.03	6.32
2010	5.60	0.74	0.02	5.90
2011	5.50	0.75	0.03	5.76
2012	5.60	0.73	0.02	7.41
2013	5.50	0.56	0.01	6.34

B. Mann-Kendall trend statistics of annual rainfall, mean annual maximum and minimum temperature dataset from 1999-2013

				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**
MAXIMUM TEMPERATURE	*1999*	*2013*	*15*		-0.55		-0.017	-0.094	0.099	-0.076	0.051	35.20	35.77	34.47	35.58	34.95
MINIMUM TEMPERATURE	*1999*	*2013*	*15*		-0.99		-0.027	-0.141	0.045	-0.116	0.020	22.99	23.87	22.42	23.65	22.56
RAINFALL	*1999*	*2013*	*15*		-1.39		-26.567	-82.212	15.471	-63.883	7.356	1129.70	1372.56	862.37	1307.03	901.99

APPENDIX IV

Questionnaire survey for inhabitants of the selected communities for Data Collection: name of community ……………………………………………………………

Section A: Socio-demographic information of food crop farmers

No.	**Questions**	**Response options**
	Community	……………………………..
1	Sex	1. Male[ ] 2. Female [ ]
2	Age	1. 25-30 years [ ] 2. 31-40years[ ] 3. 41-50years[ ] 4. 51-60years[ ] 5. 61+years[ ]
3	Marital status	1. Married [ ] 2. Single[ ] 3. Divorced [ ]
5	Income per month	1. Below GH¢20[ ] 2. GH¢20-40 [ ] 3. GH¢40-60[ ] 4. GH¢ 60-100[ ] 5. Above GH¢ 100 [ ]
6	Level of education	1. Primary school[ ] 2. Middle school [ ] 3. Secondary [ ] 4. Tertiary [ ] 5. Never been to school [ ]
7	What is the size of your Farmland	1. 1-3 acres 2. 4-6acres 3. 7-9 acres 4. 10-15 acres 5. 16- 20acres 6. 21-25 acres
9	What type of crop do you cultivate in the wet season	**(Tick all that apply)** 1. maize[ ] 2. millet [ ] 3. vegetables [ ] 4. rice [ ] 5. ground nut[ ] 6. sorghum [ ] 7. watermelon 8. soybean 9. beans 10. Others, specify…………………
10	What types of crops do you cultivate in the dry season?	**(Tick all that apply)** 1. maize[ ] 2. millet [ ] 3. vegetables [ ]

		4. rice [ ] 5. ground nut[ ] 6. sorghum [ ] 7. watermelon 8. soybean 9. beans Others, specify…………………………
11	Do you solely rely on rainfall for the cultivation of crops? If No indicate the kind of irrigation you rely on.	1. Yes [ ] 2. No [ ] ……………………………………………………… ………………………………………………………

Section B: Climatic trends and food crop production

I. Temperature variation and food crop production

12	Have you observed any temperature variation in the past 15 years?	1. Yes[ ] 2. No[ ] 3. I do not Know [ ]
13	If yes, what is the manifestation of temperature variation you have observed in the past 15 years	1. Increased in temperature [ ] 2. Decreased in temperature [ ] 3. Sometimes high other times low [ ]
14	Has the manifestation you observed affected crop production in the past 15 years	1. Yes [ ] 2. No [ ]
15	If Yes which type of crop(s) was/were greatly affected within that period? List them	……………………………………………… ……………………..…………………… ………………………………………………
16	How was/were the crop(s) listed above affected	1. Increased crop yield [ ] 2. Reduced crop yield [ ] 3. Crop failure [ ] 4. Others, specify…………………………

II. Rainfall variation and food crop production

17	Have you observed any rainfall variation in the past 15 years	1. Yes[ ] 2. No[ ] 3. I do not know [ ]
18	If Yes what are the manifestation for rainfall variation you have observed in the past 15 years?	**Tick all that apply** 1. Increased the amount of rainfall [ ] 2. Reduced the amount of rainfall [ ] 3. Increased the length of rainfall season [ ] 4. Reduced the length of rainfall season [ ] 5. Sometimes reduce the amount of rainfall and other times increased the amount of rainfall [ ] 6. Sometimes increased the length of rainfall season and other times reduced the length of rainfall season [ ] 7. Others, specify ………………………………………………
19	Has the manifestation you observed in the past 15 years affected crop production?	1. Yes [ ] 2. No [ ] 3. I do not know [ ]
20	If Yes which types of crop(s) was/were mostly affected. List them	…………………………………………………………………. ………………………………………………………………….
21	How was/were the crop(s) listed above affected.	1. Increased crop yield [ ] 2. Reduced crop yield [ ] 3. Crop failure [ ] 4. Others, specify………………………………………………
22	Has rainfall affected the growing season in the past 15 years. Please specify the year in which rainfall affected the growing season?	1. Yes [ ] 2. No [ ] 3. I do not know [ ] ………………………………………………………………….
23	If yes how has it affected the growing season	1. Reduced the length of growing season [ ] 2. Prolong the length of growing season [ ] 3. Maintained the length of growing season [ ]
24	With reference to your answer in question 22, how has that affected crop yield.	1. Moderately reduced crop yield [ ] 2. Severely reduced crop yield [ ] 3. Moderately increased crop yield [ ] 4. Massively increased crop yield [ ]

iii. Extreme climatic event and food crop production

25	Have you observed any extreme climate event for the past 15 years	1. Yes [ ] 2. No [ ] 3. Don't know[ ]
26	If Yes what was the manifestation of extreme climatic event have you observed	**Tick all that apply** 1. Drought [ ] 2. Flood [ ] 3. Strong winds [ ]
27	Can you recall the year(s) in which you observed climate extremes in the past 15 years?	………………………………………………………………
28	With reference to your answer in question, has extreme climatic event affect crop production? If yes list the type of crop(s) was/were greatly affected	1. Yes [ ] 2. No [ ] 3. I do not know [ ] ………………………………………………………… …………………………………………………………
29	How was/were the crop(s) affected	1. Increased crop yield [ ] 2. Reduced crop yield [ ] 3. Crop failure [ ]

Vulnerability of food crop farmers to climate variability

<u>**Social Asset**</u> 30. Do you belong to any association or groups? If yes Kindly list them?	1. Yes [ ] 2. No [ ] …………………………………………………………………… ……………………………………………………………………
31. If yes, what sort of benefits do you gain from the associations in times of crop failure? Please list them.	…………………………………………………………………… ……………………………………………………………………
32. If you don't belong to any association, where do gain benefit in times of crop failure? Please indicate the sort of benefit you gain.	…………………………………………………………………… ……………………………………………………………………
<u>**Financial Asset**</u> 33. Do you have access to credit facility for your food crop production? If yes, list the financial institutions.	1. Yes [ ] 2. No [ ] 3. Don't know [ ] ……………………………………………………………………
34. How does the financial institution respond to you in times of crop failure due to extreme climatic conditions?	…………………………………………………………………… …………………………………………………………………… ………………

35. Have you insured your food crop farm? If yes, list the benefits you derived from it.	1. Yes [ ] 2. No. [ ] …………………………………………………………………
36. Do you have livestock or poultry? List the types and numbers of livestock.	1. Yes [ ] 2. No [ ] ……………………………………………………………………
37. Do you receive remittances from family and friends whenever there is crop failure or low crop yield	1. Yes [ ] 2. No [ ]
38. Are the remittances enough to offset what has been lost? Explain	1. Yes [ ] 2. No [ ] ………………………………………………………………… …………………………………………………………………
Physical Asset 39. Do you have access to water for the crop production in the dry season? Please indicate the kind of irrigation facilities you accessed?	1. Yes [ ] 2. No [ ] ……………………………………………………………………
Vulnerability of livelihood 40. Have you observed reduction or increase in your crop yield?	1. Increased [ ] 2. Decreased [ ] 3. The same (no reduction or increment) [ ]
41. How has the reduced crop yield or crop failure as a result of extreme climatic conditions affected your living conditions?	**(Tick all that apply)** 1. Inability to afford three square meals a day [ ] 2. Reduce income level [ ] 3. Inability to meet health needs of my household [ ] 4. Inability to meet educational needs of my children [ ] 5. Inability to save at bank/ micro finance institutions [ ] Inability to diversify livelihood [ ] 6. Others, specify…………………
42. Do you agree that climate variability has adversely affected your livelihood conditions?	1. Yes [ ] 2. No [ ] 3. Don't know [ ]
43. If Yes, how does it affect your livelihood?	…………………………………………………………………… …………………………………………………………………
44. Do you have access to information on weather forecast	1. Yes [ ] 2. No [ ]
45. If yes, how do you apply such information in the cultivation of your crops?	1. Weather Station [ ] 2. Radio [ ] 3. Television [ ] MoFA [ ]
46. Has the weather	1. Yes [ ]

information helped you in the cultivation of your crops?	2. No [ ]
47. If **No** to question **46**, do you think access to climate information/weather forecast is necessary in the cultivation of crops?	1. Yes [ ] 2. No. [ ] 3. Don't know [ ]
48. How would the information help you in the cultivation of crops?	……………………………………………………………… ……………………………………………………………… ………………………………………………………………

Section E: Adaptation strategies of food crop farmers in response to climate variability.

49. What are the adaptive strategies that you employ in response to extreme climatic conditions? List the short and long term strategies.	Coping strategies……………………………………………. ……………………………………………………………… Adaptation strategies……………………………………… ………………………………………………………………
50. Are the adaptive strategies you employed effective?	Coping strategies 1. Yes [ ] 2. No [ ] Don't know [ ] Adaptation strategies 1. No [ ] 2. No yes [ ] 3. Don't know [ ]
51. Have you been trained by any institutions in relation to adaptive strategies to climate variability on food crop production in the community? List the institutions who trained you.	1. Yes [ ] 2. No [ ] ……………………………………………………………… …
52. If yes, what kind of training were you given?	………………………………………………………………
53. Has the training you had enabled you to develop your adaptive capacity in responding to climate variability?	1. Yes [ ] 2. No [ ] 3. Don't know [ ]
54. Do you engage in other sources of livelihood activities (other economic activities) in response to your vulnerability to climate variability? List them If no give reasons why you do not engage in other livelihood activities	1. Yes [ ] 2. No [ ] ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………..
55. How sustainable is the type of livelihood options mentioned in question 54?	………………………………………………………………

56. List some of the challenges you face in the course of adapting to climate variability	1. Very sustainable [ ] 2.Sustainable [ ] 3.Not sustainable [ ]
57. What do you think should be done to solve these challenges	…………………………………………………………………

APPENDIX V

Interview guide for Key informants (Officials of Ministry of Food and Agricultural) No.

1. Are you aware of climate variability in the municipality?

...…………………………………………………………………………………………

2. Have you observed any variability in temperature for the past 15 years? If you have what the manifestations of temperature variation

   …………………………………………………………………………………………
3. In your view have you observed any variability in rainfall pattern in the municipality for the past 15 years? If you have what are the manifestation of rainfall variation

   …………………………………………………………………………………………
4. How frequent have you observe this/these manifestation(s)……
5. In your view have you observed any trend in climate variables in relation to food crop production for the past15 years…………………………………
6. In your view, has the variability of climate variables (temperature and rainfall) affected crop production in the municipality? …………………………
7. Have you observed any relationship between extreme rainfall variability and food crop production?...

   Have you observed any extreme climatic events in the past 15 years? Please list them and specify the year you observed extreme climatic event.

   …………………………………………………………………………………………
8. Has climate extreme affected crop production? …………………
9. How has climate extreme affected food crop production? ……………
10. In your view, has climate variability on food crop production affected the livelihood activities of food famers in the municipality?............................
11. Do you provide any assistance to farmers in times of crop failure due to extreme climatic conditions?

…………………………………………………………………………………………

....

15. Do you organize any training for food crop farmers on adaptive capacity in response to climate variability? Please specify the kind of training …………………

16. How effective is the training?...
17. What are some of the challenges you encounter in the process of the training?

    …………………………………………………………………………………………

    …………………………………………………………………………………………
18. What do you think could be done to solve these challenges? ………
19. Kindly mention some of the major pressing problems that make it difficult to provide the necessary adaptive capacity training for food crop farmers in relation to climate variability

…………………………………………………………………………………………

…………………………………………………………………………………………

What do you think is the best pragmatic measures to ensure sustainable adaptive capacity of food crop famers?...

APPENDIX VI

Interview guide for Key informants (Officials of Savanna Agricultural Research Institute (SARI). No. …………..

1. Are you aware of climate variability in the municipality?

...…………………………………………………………………………………………

… 2. In your view, have you observed any variability in temperature for the past 15 years? If you have what are the key manifestation of temperature variability................

…………………………………………………………………………………………

…………………………………………………………………………………………

3. Has the manifestation affected crop production?..
4. In your view have you observed any variability in rainfall pattern in the municipality for the past 15 years? If you have what are the key manifestation of rainfall variability

   ………………………………………………………………………………………

   Has manifestation of rainfall variability affected food crop production?.........

5. Have you observed any extreme climatic events within the past 15?..................
6. How many years of extreme climatic events have you witnessed? Kindly state the year(s) ………………………………………………………………………………

   Has the extreme climatic events affected food crop production?...........
7. How has it affected crop production?..........................

   ………………………………………………………………………………………
8. In your view, has climate variability on food crop production affected the livelihood activities of food famers in the municipality?

…………………………………………………………………………………………

9. Are farmers aware of the institution's existence and roles in the municipality?

   ………………………………………………………………………………………

   ………………………………………………………………………………………

10. Does the institution has a role in improving food crop productivity in the municipality?

    Yes [ ] No [ ]
11. Do you provide any technical assistance to farmers, if the institution does what sort of assistance do you provide?

…………………………………………………………………………………………

16. How effective is the training?..

…………………………………………………………………………………………

17. What are some of the challenges you encounter in the process of providing that technical assistance?

…………………………………………………………………………………………

18. What do you think could be done to solve these challenges?

…………………………………………………………………………………………

APPENDIX VII

Interview guide for Key informants (Officials of Bawku weather station) No. …………..

1. Are you aware of climate variability in the municipality?
...………………………………………………………………………………………………
2. In your view, have you observed any variability in temperature for the past 15 years? If you have what are the manifestations of temperature variability

   ………………………………………………………………………………………………
3. In your view have you observed any variability in rainfall in the municipality? If you have what are the manifestations of rainfall variability
   ………………………………………………………………………………………………
4. How frequent have you observe this/these manifestation(s)…………
   ………………………………………………………………………………………………
5. Are farmers aware of the weather station and the role it plays in the municipality?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
6. Is the weather station responsible for providing weather related information such as extreme climatic conditions (erratic rainfall, prolong drought) to farmers?
   ....
   ....
7. In your view, are famers therefore informed of any projected extreme climatic conditions?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………

APPENDIX VIII

Focus Group discussion: Discussion guide for focus group.

1. Have you observed any variability in temperature and rainfall in your community?
2. If yes, how long have you observed this variability?
3. What do you think are the causes of this variability?
4. What evidenced do you use to prove this variability?
5. What are the manifestations of this variability in the temperature and rainfall?
6. Has this variability affected crop production for the period you observed as compared to years before you noticed this variability?
7. Have you observed a reduction in the length of the growing season?
8. What are the effects of the observed variability in temperature and rainfall on food crop production for the past 15 years.
9. What other factors aside temperature and rainfall contribute to the variation of crop production.
10. What crops are mostly affected by the observed variability?
11. How do you respond to these effects of climate variability on food crop production in the short run and long run?
12. Do you belong to an association?
13. Have you insured your crop?
14. Do you have access to credit facility?
15. Do you receive remittances from family and friends?
16. Do you have access to information on weather forecast?
17. Do you have access to water for irrigation?
18. Are your strategies effective?
19. What are some of the challenges you face in responding to the effects of extreme climatic conditions on food crop production.
20. Is there any adaptive capacity training for you by any agency or institution directly involve in food crop production
21. How has the effects of extreme climatic conditions on food crop production affected your livelihood?
22. Do you engage in other sources of livelihood activities in your community to supplement the income derived from farming?
23. What type of livelihood activities do you engage in?
24. Are the livelihood activities sustainable?
25. Have you been trained by any institution?
26. Has the training enhanced your adaptive capacity?