CLIMATE CHANGE VULNERABILITY AND COPING MECHANISMS AMONG FARMING COMMUNITIES IN NORTHERN GHANA

by

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B.S., University of Ghana, Legon, 2008

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2012

Approved by:

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Abstract

This study examines the effect of extreme climatic conditions (drought, flood, and bushfires) on the livelihood of households in the Bawku West district of Ghana. The research identified the mechanisms with which households cope in such situations, and analyzed factors influencing the adoption of coping strategies for flood, coping strategies for drought, and coping strategies for bushfires. Data for the study were collected in selected villages across the district in the aftermath of the 2007/2008 extreme climatic events (a prolonged drought period followed by an erratic rainfall). A binary logit regression (BLR) model was then specified to estimate factors that influence the adoption of a given coping mechanisms. Results from the BLR model indicate that literacy level, membership with an FBO, household income, and location of households had positive and significant impacts on adaptation to drought. Similarly, source of seeds for planting, membership with an FBO, household income, and farm size had positive significant influence on adaptation to flood. Adaption to bushfire was positively influenced by radio ownership, seed source and income. The main effect of these climatic extreme events on households included destruction of crops, livestock and buildings; food and water shortage; poor yield or harvest and limited fields for livestock grazing. Therefore, government policies should be geared towards creating revenue generating channels and in strengthening institutions that provide access to farm credit, readily available improve seeds and extension. Additionally, policies that expedite information dissemination through radio and other public media will enhance households' adaptive capacity.

Keywords: climatic conditions, coping, binary logit, drought, flood, bushfires

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List of Abbreviations

DFO	Dartmouth Flood Observatory
UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
UNDP	United National Development Program
WHO	World Health Organization
GDP	Gross Domestic Product
BLR	Binary Logistic Regression
BWDA	Bawku West District Assembly
NGOs	Non-Governmental Organizations
UN	United Nations
CDF	Cumulative Distribution Function
FBO	Farmer Based Organization

Acknowledgement

I am deeply thankful to my major advisor, Dr. Andrew Barkley. His inspiring guidance, encouragement, advice and the patience to go through my work several times to correct any possible error is indeed invaluable. To my committee members: Dr. Timothy Dalton and Dr. Nathan Hendricks, I would also like to register my profound appreciation for their contributions. Their modification to my model has improved the quality of this study. I am genuinely indebted to the support, love, care, advice and encouragement from my friends and family. Words cannot describe how much I cherish every moment spent with you guys and the joy thoughts of each one of you brings to my life.

Finally, my utmost and sincerest gratitude goes to the Lord Almighty for His faithfulness, provision, protection and love throughout my entire education. I have come thus far, because of you, Lord.

Chapter 1 – Introduction

1.1 Background

The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defined climate change as ‘‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.’’ This paper explores climate change vulnerabilities and coping strategies employed by farming communities in Northern Ghana to alleviate the negative impact of potential extreme events as drought, flood and bushfires. The issue of climate change has been a central focus in many global discussions concerning poverty, food insecurity, environmental sustainability, human health, global economy, and many other socio-political discourses. World population growth has continued, and although the demand for food production has more than doubled since the pre-industrial era, productivity is declining due to climate change and climate variability. Empirical evidence supports climate change-induced decline in crop and livestock productivity globally (IPCC, 2007; Deressa et al., 2008; Kurukulasuriya and Mendelsohn, 2006a; IISD, 2007; Lobell et al., 2008), more especially in weather-sensitive agricultural production regions such as sub-Saharan Africa.

The impact of climate change vulnerability varies globally. However, the adverse effect of climate change is particularly devastating in developing regions, especially sub-Saharan Africa (Kandji et al., 2006) as a result of rapidly declining precipitation levels, increasing temperatures, low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adoption (Kurukulasuriya and Mendelsohn, 2006b), limited infrastructure, illiteracy, lack of skills, low management capabilities, weak institutions, and information (UNFCCC, 2007), and the absence of comprehensive national adaptation policy among others. According to the IPCC (2007), vulnerability is defined as “the degree to which an environmental or social system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes” (McCarthy et al., 2001). The scope of vulnerability of Africa to climate change is disquieting, with one third of African people already living in drought–prone areas. In the 2006 UNDP human development report, overexploitation of land resources including forests, increases in population, desertification, and land degradation were identified as additional constraints for African countries to cope with climate variability (UNDP, 2006).

Temperatures are expected to rise fastest in Africa and a decline in rainfall volume is also anticipated. According to the IPCC (2007), sub-Saharan Africa is likely to experience increases in both minimum (1.8^{o}C) and maximum (4.7^{o}C) temperatures. Minimum and maximum precipitation levels are likely to change by -9% and 13% respectively (Christensen et al., 2007). These factors, coupled with the volatile nature of the socio-political economy/environment of the continent, places it at a higher risk level. Many African countries already battle with poverty, low agricultural productivity, and other environmental-related issues without climate change. An added impact of climate change is critical to the economic development of the region. The region is lagging in the development of public infrastructure, and in strengthening the capacity of existing institutions to mitigate climate change.

The impact of climate change on agricultural productivity in low income countries is relatively higher compared to other sectors of their economy and the magnitude of this impact is expected to either remain same or intensify (Pearce et al., 1996; McCarthy et al., 2001; Tol, 2002). The widespread debate and increasing global concern on climate related issues, especially in Africa, is partly drawn from this assertion. There has therefore been a mounting fear as to how agriculture-dependent sub-Saharan economies cope with climate extremes and climate variability. To this end, the unanswered question on climate change related issues about Africa is: ‘‘will African agriculture survive climate change?’’(Kurukulasuriya et al., 2006b). Though there have been mixed predictions on the impact of climate change on African agriculture, it is established that African countries cannot veer off the impact of climate change and climate variability on the economic well-being of their growing population and expanding food demand. A general consensus points to declining net revenues with warming and decreasing precipitation levels for dry land crops and livestock production in the region (Kurukulasuriya and Mendelsohn, 2006a). Cereal yields in tropical regions are projected to decline markedly due to climate change vis-à-vis comparable temperate regions. According to a report by the UN Millennium Project (2005), domestic per capita food production in sub-Saharan Africa declined by 10% between 1985 and 2005. Hence current food production in the region is not meeting the needs of the rising African populace (UN Millennium Project, 2005).

The Ghanaian agricultural-dependent economy is also estimated to suffer severe economic consequences from climate change. In that, Ghana’s economy essentially depends on climate-sensitive sectors such as agriculture, forestry, and hydroelectric energy. The needed capacity for adaptation by these sectors, particularly the agricultural sector is greatly lacking. Albeit Ghana’s lower middle income status, well over 50% of the country’s total workforce currently depends on subsistence-rain-fed agriculture for their daily livelihood. The country’s poverty gap keeps widening and the rural poor who are mainly peasant farmers, stands at a higher risk of climate variability and any extreme event. Northern Ghana is considered to be particularly vulnerable to climate change, primarily drought and flood because of the relatively low precipitation levels, higher temperatures, subsistence based farming, higher poverty level, poor infrastructure, high illiteracy rate and limited access to information compared to the other regions of Ghana.

The poverty level is highest in Northern Ghana[1] and temperature levels also likely to increase the most in the Northern, Upper East and Upper West regions of Ghana, by 2.1 to 2.4 ^{o}C by 2050 (World Bank, 2010). Though precipitation forecast for the entire country shows a cyclical pattern over the next half century, Northern Ghana is predicted to be relatively drier (World Bank, 2010). The occurrence of normal seasonal rainfall displaces 30% of the communities settled along the banks of the portion of the Black Volta that flows through Northern Ghana each year. Estimates from the climate baseline trends for Ghana in the fourth assessment report of IPCC reveals an alarming impact of climate change in altering the climatic pattern in Ghana. The average number of hot days and hot nights increased by 48 and 73 days per year, respectively, between 1960 and 2003. The average number of cold days and night decreased by 3.3% and 5.1% of days respectively in the same period. This trend indicates the gradual alteration of Ghana's weather pattern as a result of the changing climate in the country (McSweeney et al., 2012).

The current contribution of agriculture to Ghana's total GDP is projected to decline between 3 to 8 percent by 2050. A major contributory factor to this decline has been closely linked to unfavorable projected climatic conditions that are likely to have adverse effect on agricultural productivity, predominantly in the north of Ghana. The main diet in most Ghanaian homes constitutes mostly cereals – millet, sorghum, maize, and rice – which are produced mainly

[1] Poverty levels in Northern Ghana range between 70 percent and 90 percent (GSS, 2004).

in the north of Ghana.[2] A decrease in production and/or yield of these commodities as a result of climate change would worsen the already alarming threat of food security, particularly in the Northern sector and severely affect the economic development of the region. Decades of data show a decrease in yield and production whenever the northern part of Ghana, particularly, experiences any adverse agro-climatic change such as flood and drought. The ripple effect has always been food shortage, higher prices for agricultural commodities and other products produced from agricultural raw materials, not only in the northern regions, but the country as a whole. Though the focus of this paper concentrates on the relationship between climate change and agriculture, other sectors of the economy, directly or indirectly related to agriculture are also impacted such as the health, service and industry sectors that thrive on agriculture.

The survey for this study was conducted near the end of 2008, almost a year after several towns and villages in the north of Ghana were severely hit by the worst flood ever since the 1980's. Although the impact of this flood was most deleterious in Northern Ghana, virtually every single country in West Africa including Sudan and Chad was hard hit. This flood event was ranked by the Dartmouth Flood Observatory (DFO) as one of the three most devastating flood events in the world that year (Tschakert et al., 2009). It is worth noting, however, that the 2007 flood season which occurred between July and September was preceded by a long period of drought (from January to May). Such extreme wet periods and accompanying flooding are anticipated to increase by 20% in the next decades in West Africa (Christiansen et al., 2007).

This paper examines both reactive and proactive measures that farm households use in response to climate. Proactive in the sense that the yearly weather pattern of Northern Ghana always has a period of drought which is usually considered a "normal" condition though the

[2] Sorghum, millet, groundnut, beef and soybeans produced in Northern Ghana constitute approximately 70 percent of total national production (World Bank, 2010).

severity and length of the drought period differs yearly. It is assumed that households in this area already have adopted some measures to adapt to such recurring events. Bushfires have been identified as another resultant effect of drought which normally occurs when farmers start to prepare their land for cultivation at the end of the drought season. Reactive measures are used to cope with climatic extreme events that are atypical to the region such as flood. There are additional coping measures that require the intervention of government and other non-governmental organizations. Nonetheless, the underlining fact remains that these measures only reduce the severity of the impact of climate variability and do not or cannot eliminate it completely. A good understanding of the aftermath effect of climate change on the livelihood of farming households, possible coping measures employed, and factors influencing the choice of a specific coping strategy to climate change will enhance policies towards tackling the challenges that climate change poses to farming communities.

1.2 Objectives of Study

The general goal of the study is to clearly understand the level of vulnerability of households in the Bawku West of Ghana to climate change, and how they cope with climate variability. The specific objectives are as follows:

1. To determine the socio-economic characteristics of farming households exposed to climate change and climate variability;
2. To identify and prioritize the effect of climate risk encountered by farming households;
3. To analyse the determinants of coping mechanisms used by households in responses to climate change and climate variability.

1.3 Thesis Organization

This study is organised into seven chapters. This first Chapter has given an introduction to the study. In Chapter Two, existing literature is reviewed in relation to the study. The next Chapter gives an overview of the data used, and a description of the study area. Chapters Four and Five provide the theoretical framework and methodology, respectively, which explain how the study objectives were achieved. Results of the study are analysed and presented in Chapter Six. Finally in Chapter Seven, conclusions are deduced, and key policy recommendations are proposed based on the findings of the study.

Given the objectives and general overview of the study, the next Chapter reviews relevant literature related to the study and climate change in Ghana.

Chapter 2 – Review of Literature

2.1 Introduction

This Chapter has four sections on literature reviewed in relation to the study. A review of the key concepts related to the study, and the state of changing climate in Ghana are presented in the first two sections. The third section explores the effect of climate change on agricultural productivity in Ghana. The last section reviews the vulnerability of crop production to climate change in Ghana.

2.2 Key Concepts Related to Study

The section begins by giving a succinct review of some of the key concepts – drought and flood – in the present study as used in the literature. *Flood* is defined by the EU Flood Directive as "a temporary covering by water of land not normally covered by water which may include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude flood from sewerage systems" (European Union, 2006). Floods occur when drainage basins reach maximum capacity and are unable to absorb additional precipitation resulting from certain weather phenomena such as heavy rains, tropical cyclones and other events (Hirschboeck, 1991). Few (2003) stated that 'a typology of flooding can comprise overflow of rivers produced by prolonged seasonal rainfall, rainstorms, snowmelt and dam-breaks, accumulation of rainwater in low-lying areas with high water tables or inadequate storm drainage, and intrusion of seawater on to land during cyclonic/tidal surges.' However, the most common cause of floods is heavy rains (Few, 2003), which accounted for about 69% of floods in 2007 (Tshakert et al., 2009). In the case of Ghana, human activities which modify the nature of the ground surface and its hydrological response to precipitation facilitate the incidence of floods (Karley, 2009).

The concept of *drought* has divergent meaning across disciplines, regions or zones and the severity of impact. Regardless, some authors have attempted to give a general perspective on what drought is. According to Wilhite et al. (2000) drought is described as a natural hazard that differs from other hazards because it has a slow onset, progresses over months or even years, and affects a large spatial region and causes little cultural damage. Their description borders around the long progressive nature of drought which contrast other natural disasters (flood, hurricanes etc.). Unlike drought, most of these disasters have a much quicker impact and last only for short periods. The persistent or lingering nature of drought is again echoed in its definition found in the encyclopedia Britannica. As the lack or insufficiency of rain for an extended period that causes a considerable hydrologic imbalance and, consequently, water shortages, crop damage, stream flow reduction and depletion of groundwater and soil moisture (Dietz et al., 2001). Drought is an extreme rainfall deficit and the resulting periods of low flow of water, which can have severe effects on water managements in terms of river pollution, reservoir design and management, irrigation and drinking water supply (Hisdal and Tallaksen, 2000). The definition of drought differs due to a number of reasons: it affects all climatic regions at varying degrees, it affects diverse economic and social factors and the demands people place on water differs markedly across regions (Wilhite, 1996; Dietz et al., 2001; Moneo and Iglesias, 2004). This makes defining drought region-specific and dependent on the severity of its impact and the importance of water to the society or region affected.

According to Wilhite and Glantz (1985), the definitions for drought can be placed under two broad categories: (1) operational definition (relates current situation to some historic mean) and (2) conceptual definition (take account of the effect and concept of drought). Drought may also refer to a meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought. Meteorological drought is defined as a reduction in rainfall supply compared with a specified average condition over some specified period (Hulme, 1995). Meteorological drought is considered region-specific due to the variability across regions in the atmospheric conditions that result in deficiencies of precipitation (Olaleye, 2010). Agricultural drought ensues when the amount of water in the soil no longer meets the need of a particular crop (Backerberg and Viljoen, 2003). From the literature, indicators of agricultural drought includes but not limited to crop yield response to water stress (Kumar and Panu, 1997) and the degree of departure from expected yield (Wu and Wilhite, 2004). Hydrological drought is related to low river flows and low water levels in rivers, lakes and groundwater. The incidence of any of these drought form(s) can distort the equilibrium level of some economic goods and services by reducing supply. This condition defines a socioeconomic drought.

2.3 Climate Change and Climate Systems in Ghana

Ghana is characterized by a tropical climate and strongly influenced by the West African Monsoon. Movement of the Inter-Tropical Convergence Zone (ITCZ) between the North and South tropics brings about dry and wet periods, the two main climatic seasons in Ghana (McSweeney et al., 2012). Dry periods are experienced when the 'Harmattan' wind blows north-easterly while the south west wind brings about the wet seasons. The average annual rainfall ranges from 800 to 2200 mm and decreases from south to north and eastward (UNFAO, 2005). Ghana is divided into six agro-ecological zones: Sudan, Guinea and Coastal Savanna zones, the Forest-Savanna Transitional zone, the Semi-deciduous Forest and the High Rainforest Zones –

reflecting the different climatic and vegetation distribution of the country. Table 1 shows the climatic distribution by agro-ecological zone. The Northern savannah zone comprising the Guinea savannah and Sudan savannah has a unimodal rainfall pattern with rainfall typically in May to September. The other agro-ecological zones are characterized by a bimodal rainfall pattern.

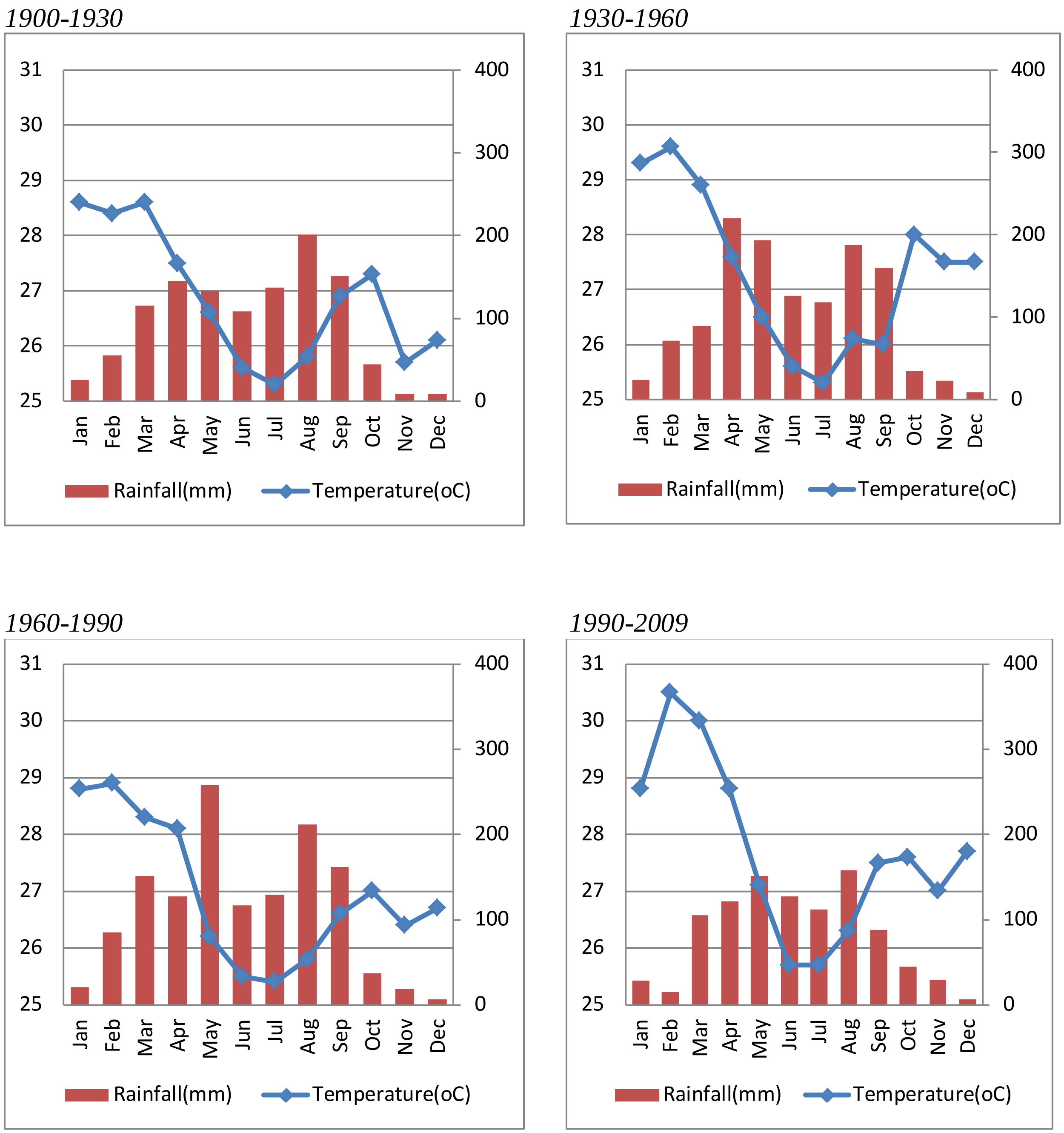
Table 1: Climate distribution by agro-ecological zones

Agro-ecological zone	Mean annual rainfall (mm)	Range (mm)	Major rainy season	Minor rainy season
Rain Forest	2200	800-2800	March-July	Sept.-Nov.
Deciduous Forest	1500	1 200-1600	March-July	Sept.-Nov.
Transitional Zone	1300	1 100-1400	March-July	Sept.-Oct.
Coastal Savannah	800	600-1200	March-July	Sept.-Oct.
Guinea Savannah	1000	800-1200	May-Sept.	Nil
Sudan Savannah	1000	800-1200	May-Sept.	Nil

Source: UNFAO, 2005.

In Figure 1 the average monthly rainfall and temperature for Ghana from 1900 to 2009 over 30-year periods are presented. The lowest average monthly (82.5mm) and maximum rainfall (158.3mm) quantities in a century were both recorded in the 1990-2009 periods. Temperature levels are typically high in January, February and March, when rainfall levels are generally low and low in June and July when rainfall levels are well above average. Maximum temperature rose in the 1930-1960 period from 28.6^{o}C to 29.6^{o}C with the minimum temperature not changing. The 1990-2009 periods had an increase in both minimum and maximum temperatures to 25.7^{o}C and 30.5^{o}C respectively, an indication of a changing climatic pattern in Ghana. This trend is expected to continue since temperature levels are projected to rise in coming decades unless certain measures are put in place to reverse the direction of the changing climate. In a UNDP survey, mean annual temperatures for Ghana are projected to increase by 1.0 to 3.0°C by the 2060s, and 1.5 to 5.2°C by the 2090s (McSweeney et al., 2012).

Figure 1: Average Monthly Rainfall and Temperature for Ghana



Source: Data adapted from The World Bank Climate Change Knowledge Portal

Rainfall predictions for the semi-deciduous and evergreen rainforest zones of Ghana show decline in rainfall values by 2020, 2050 and 2080. It is estimated that rainfall values for semi-deciduous forest zone will drop by -2.8, -10.9 and -18.6% by 2020, 2050 and 2080 respectively. That for the evergreen rainforest zone is also projected to decline by -3.1, -12.1 and -20.2% respectively by 202, 2050 and 2080 (Anim-Kwapong and Frimpong, 2004).

2.4 Climate Change and Agricultural Productivity in Ghana

Agriculture continues to provide employment and livelihood for a large proportion of Ghanaians, despite its declining contribution to total GDP. Agricultural production is predominantly subsistence or small scale and productivity is already low though farmers are understood to be efficient but poor (Schultz, 1964). Increases in productivity are realized mostly with the addition of new lands to cultivation. Fewer advances in technology combined with the changing climate which is not suitable for producing certain staples makes the agricultural sector the most vulnerable. Climate change is expected to impact agricultural productivity in Sub-Saharan Africa, especially cereal production. A study by Sagoe (2006) also indicated an impact on root and tuber production by climate change in Ghana. The CROPSIM-cassava and CROPGRO (ARGRO980)-tanier models were used to generate growth and yield in cassava and cocoyam, respectively, in years 2020, 2060 and 2090 given expected changes in climate. A decline in cassava productivity is expected in 2020, 2050 and 2080 by 3%, 13.5%, and 53%, respectively. Cocoyam productivity will reduce by 11.8%, 29.6%, and 68% by the 2020s, 2050s and 2080s respectively (Sagoe, 2006). The Crop Environment Resource Synthesis (CERES) model has been used to assess the impact of climate change on cereal production in Ghana. In a report by the Netherlands Climate Assistance Programme on women’s livelihoods and vulnerability to climate change in Ghana, yield changes in maize and millet were estimated using the CERES model. Maize yield in the Transition zone is anticipated to decrease by 6.9 percent in the year 2020, however no change in millet yield is expected because millet is more drought tolerant and, therefore, insensitive to temperature rise

2.5 Vulnerability of Crop Production to Climate Change in Ghana

Climate change is predicted to have undesirable consequence on agricultural production and food security in sub-Saharan Africa (Boko et al., 2007). This impact, however, is expected to vary spatially across and within countries in the region (and across socio-economic groups). Areas with high climate-sensitive agricultural production systems due to their over reliance on rain-fed subsistence agriculture have been identified as the most vulnerable to climate change. Most of these countries already battle with the issues of poverty, food insecurity, health, and other basic social needs. The compound effect of climate change is therefore deleterious to the growth of the economies in such countries placing them at the high end of the climate change vulnerability spectrum. Antwi-Agyei et al. (2011) provide a comprehensive map of vulnerability in crop production to climate change, particularly drought, for all the regions in Ghana and some selected districts across the country. This section draws heavily from their analysis. They used a three-stage method (crop yield sensitivity index, exposure index and crop drought vulnerability index) to determine the vulnerability of crop production (specifically maize at the regional level, and sorghum and millet at the district level) to drought. The crop (or maize) yield sensitivity indices for all the ten regions showed the Upper East and Upper West regions as the most sensitive regions to drought. In terms of adaptive capacity to drought, the three regions in the northern sector: the Northern region, Upper West and Upper East, were identified to have the lowest capacity to cope with drought. These regions invariably were noted as the most vulnerable to drought in Ghana. Their results are in agreement with several studies, which designate the northern sector of Ghana as the most vulnerable region of Ghana. The three regions in the north have the highest poverty level, highest proportion of rural population, poor agro-climatic systems and are predominantly subsistence farmers relative to the southern half of the country.

Brief discussions on the climatic systems and the vulnerability of agricultural production to changes in climate in Ghana have been presented in this chapter. The next chapter explores the theory behind the model used in the study.

Chapter 3 – Theoretical Framework

The theory behind the principal model used in the study is discussed in this section. Previous literature indicates that a discrete choice model (logit or probit) is most appropriate in analyzing models with binary response dependent variables. Discrete choice models assume both deterministic utility and probabilistic decision process (Ben-Akiva and Bierlaire, 2003), and have been used extensively in the literature to model adoption decision studies involving binary or dichotomous choices. In this study, the Binary Logistic Regression model (BLR) was employed to investigate factors that influence the choice of a given coping measure since the number of choices available to households is only two (adopt or not adopt a given coping strategy). A strong linkage between binary choice models and the theory of utility has been established in previous literature. Three commonly used approaches includes random utility approach, latent variable approach and non-linear or pure probability approach, lead to the logit model, and are expounded and discussed in sections 3.1, 3.2 and 3.3 respectively.

3.1 Random Utility Approach

Consumer theory suggests that individuals are rational, and if faced with the decision to choose between two alternatives, will prefer the option that provides the maximum level of utility. Against this backdrop, the choice or the adoption of a given coping mechanism by households is considered a utility maximization problem. In that regard, the choice of a given coping strategy can be considered a function of the expected utility derived from using that strategy. The utility function can be stated as

(3.1) $$U_{ia} = V_{ia} + \epsilon_{ia}$$

where U_{ia} is household *i*'s utility for adopting a given coping strategy *'a'*, V_{ia} is the systematic (or deterministic) component of utility for household *i* associated with adopting the strategy, and $\in_{ia}$ is the error associated with adoption (Train, 2003), which captures factors that influence utility but are unobserved. The random utility model assumes that household *i* will choose a given coping measure if the perceived utility from its adoption exceeds that of non-adoption i.e.

(3.2) $$U_{ia} > U_{ib} \quad \forall\, a \neq b$$

Utility levels cannot be measured due to the complexity of human behavior, but the probability of making a specific choice among alternative options is quantifiable. Therefore, the decision to adopt or use a particular strategy or not should include a probabilistic dimension. Under the binary logit model specification, the probability of household *i* adopting a given coping strategy is the probability that the utility from using the strategy exceeds the utility from not using such strategy. This is shown mathematically as depicted in (Train, 2003).

$$P(y_i = 1) = P(U_{ia} > U_{ib})$$

$$= P(V_{ia} + \in_{ia} > V_{ib} + \in_{ib})$$

(3.3) $$= P(\in_{ib} - \in_{ia} < V_{ia} - V_{ib})$$

If the distribution of the error term follows a Gumbel distribution, or a Type I extreme value distribution – also assumed to be identically and independently distributed – then the difference of the two Gumbel-distributed disturbance terms is a logistic (cumulative) distribution (Gumbel, 1958).

3.2 Latent Variable Approach

The binary logit model can be derived from an underlying unobserved or latent variable. Let y* be an unobservable or latent variable determined by,

(3.4) $$y_t^* = x_t'\beta + u_t$$

All that is observed is another variable y, where:

(3.5) $$y_t = \begin{cases} 0, if\ y_t^* \leq 0 \\ 1, if\ y_t^* > 0 \end{cases}$$

In order to estimate the function, the following assumptions are made:

1. The variance of the error term u is known, i.e. the observed data remains unchanged if variance is scaled by an unrestricted parameter,
2. The expected value of the error terms given the independent variables is zero and
3. Zero normalization threshold for the latent variable i.e. to help identify the constant term.

Given the assumptions of the distribution functions, and the specification for the latent variables, we can derive the response probabilities then as,

$$Pr(y_t = 1) = Pr(y_t^* > 0)$$

$$= Pr(x_t'\beta + u_t > 0)$$

$$= Pr\ (u_t \leq -x_t'\beta)$$

(3.6) $$Pr\ (u_t \leq -x_t'\beta) = F(x_t'\beta)$$

where F is the cumulative distribution of u. If F is symmetric about 0 (as is the case with logit models), then the standard logit model is given by

$$Pr(y_t = 1) = 1 - F(-x_t'\beta)$$

$$= F(x_t'\beta) \qquad \text{by symmetry}$$

For logistic models the type of CDF used is a Logistic CDF, hence the Logit model is therefore given as:

(3.7) $$Pr(y_t = 1) = F(x_t'\beta) = L(x_t'\beta) = \frac{e^{x_t'\beta}}{1+ e^{x_t'\beta}}$$

3.3 Nonlinear Probability Approach

In this approach the binary outcome variable Y_i (i = 1,…,T) is assumed to follow a Bernoulli probability distribution which takes on two mutually exclusive outcomes: a value of one with probability π_i and zero with probability 1- π_i :

(3.8) $$Pr(Y = 1) = \pi_i$$

(3.9) $$Pr(Y = 0) = 1 - \pi_i$$

The variable π_i(success) is defined as the probability that a household adopts a given coping strategy to climate change (or when the event occurs) and is expressed as:

(3.10) $$\pi_i = Pr(Y = 1) = 1/(1 + exp(-Y_i))$$

The term $1 - \pi_i$ (failure) is the probability of a household not adopting the given coping strategy to climate change (or when the event fails to occur) and is also specified as

(3.11) $$1 - \pi_i = Pr(Y = 0) = 1/(1 + exp(Y_i))$$

Rearranging equations (3.10) and (3.11) gives the equation for the logit model as

(3.12) $$\frac{\pi_i}{1-\pi_i} = \frac{1+exp(Y_i)}{1+exp(-Y_i)}$$

where $\pi_i/(1 - \pi_i)$ is the ratio of the probability of households adopting a given coping strategy to the probability of no adoption and referred to as the odds ratio (the odds that $Y_i = 1$). If the odds ratio is different from 1 then there is an effect of X on the probability of success (i.e. y = 1). Taking the natural log of both sides this equation gives the inverse transformation called the log odds ratio or logit.

(3.13) $$Y_i = ln\left(\frac{\pi_i}{1-\pi_i}\right) = logit$$

(3.14) $$\pi_i = logit^{-1} = \frac{exp(Y_i)}{1+exp(Y_i)}$$

There are certain limitations associated with the Bernoulli probability distribution. The assumption of each event occurring with the same chance or probability as the model presuppose is far too restrictive and requires some form of modification. It is therefore not a good model if the outcomes are widely variable.

With the theoretical framework underlining the methodology used for the study clarified, a discussion of the empirical model used for the study is presented in the next chapter.

Chapter 4 – Empirical Model

4.1 Introduction

An overview of the methods and procedures used in achieving the objectives of the study is presented in this section. The socioeconomic characteristics of respondents and the adverse effect of climate change on farming households are discussed using descriptive statistics. Climate risks encountered by farming households in the study are presented in tables, charts and graphs. In achieving the third objective, a binary logit model was used to analyze the determinant of coping mechanism used by households in responses to climate change and climate variability. The standard form of the logit model is given as (Greene, 2003):

(4.1) $$Pr(y_i = 1) = exp(\, x_i'\beta)/1 + exp(\, x_i'\beta)$$

where x_i' is a vector of explanatory variables that influence the choice of a given coping strategy, and β is the vector of parameters to be estimated. The variable y_i is a random variable, and represents the adoption of a given measure by any farming household if y_i = 1. Each farming household is faced with the decision to adopt or not adopt a given coping measure. The choice of each measure is assumed to depend on a number of socioeconomic characteristics (age, gender, marital status, household size, literacy level of household head, farm income), asset characteristics (radio ownership, mobile phone ownership, size of farmland), resource availability (access to electricity, access to formal/informal credit, farmer-to-farmer extension), and other factors (source of seed for planting, area or locality, effect of climatic events on households). The empirical model is specified as:

$$(\mathbf{4.2}) \qquad Y_i = \beta_0 + HHCHAR_i'\beta_1 + ASSET_i'\beta_2 + RESOURCE_i'\,\beta_3 + OTHER_i'\beta_4 + \varepsilon_T \qquad \forall\, i = 1, \dots \dots \dots, 15$$

Where

Y_i = coping measure i,; $HHCHAR$ = household characteristics; $ASSET$ = asset characteristics; $RESOURCE$ = resource availability; $OTHER$ = other factors; ε_T = random error term, and the β_s' are parameter estimates. The study identified 15 coping measures (dependent variables) used by households in the study area in responses to three major climate extreme events – drought, flood and bushfires.

To cope with the event of drought, households adopted to the following measures:

1. Plant drought resistant or early yielding crops
2. Did nothing
3. Plant more trees or cover crops
4. Early planting
5. Irrigation practices
6. Food storage

To cope with the event of flood, households adopted to the following measures:

1. Stop farming or building in lowland areas
2. Construction of improve drainage system
3. Did nothing
4. Modern building techniques
5. NGO or government aid
6. Early planting

In the event of bushfires, households adopted to the following measures to cope:

1. Improve farm maintenance techniques
2. Fire prevention education

3. Did nothing

This sub-section presented the general model used for the study and the variables included in the model. The subsequent sub-sections briefly discuss the methods of estimating and validating the model used.

4.2 Estimation

The method of maximum likelihood is used to estimate the parameters of the binary logit model. Assuming the observed dependent variable, y, follows a Bernoulli distribution with N independent observations, then the likelihood function for household *i* is given by:

(4.3) $$L = \prod_{i=1}^{N} \mathrm{F}(X_i'\beta)^{y_i} (1 - \mathrm{F}(X_i'\beta))^{1-y_i}$$

where $F(X_i'\beta)$ is a logistic distribution function. The idea behind maximum likelihood estimations is to choose a probability that maximizes the likelihood function so as to find the parameter value that makes the expected value of y as close as possible to the observed y. These estimates are obtained by optimizing the likelihood through a numeric optimizer. The Newton-Raphson method is the most widely used algorithm (numeric optimizer) in estimating maximum likelihood functions. For estimation purposes a log likelihood function is preferred over the likelihood estimations though both are equivalent. With logarithmic functions being monotonic a maximum of the log likelihood function will likewise be a maximum of the likelihood function.

The log likelihood function is however globally concave and this makes their model estimation relatively easy. Taking the natural log of the likelihood function yields the log likelihood function and depicted as:

(4.4) $$In\ L = \sum_{n=1}^{N} [y_i \mathrm{In} \mathrm{F}(X_i'\beta)(1 - y_i)\mathrm{In}(1 - \mathrm{F}(X_i'\beta))]$$

4.3 Marginal Effects

In logit models, the coefficient estimates shows only the direction of change in the dependent variable given a change in the independent variable(s) and the associated significance level. What it doesn't indicate is the magnitude of this change, i.e. the probability of obtaining a 1 or 0. A positive coefficient is an indication of an increase in the probability that y = 1, and a negative coefficient indicates a decrease in the probability that y = 1. The magnitude of the effect of change (marginal changes) is a derivate of the logit function and is given by

(4.5) $$\frac{\partial P_i}{\partial X_{ij}} = f(X_i'\beta)\beta_j, i = 1,2, \dots\dots, N, j = 1,2, \dots\dots, K$$

(4.6) $$= Pr(y = 1) * Pr(y = 0) * \beta_k$$

Thus marginal effect is the slope of the curve relating X_{ij} to P_i and also the probability of success times the probability of failure times the coefficient on X_{ij} .

4.4 Hypothesis Testing

The following hypothesis where Ho denotes null hypothesis and H_1 denotes alternate hypothesis is validated in the present study.

Ho: all slope coefficients are jointly equal to zero, and

H_1: at least one slope coefficient is not zero.

Three key test statistics – the Wald test statistic, the Score (or Lagrange Multiplier) test statistic and the likelihood ratio (LR) test statistic – are commonly used in validating hypothesis in discrete choice models. All of the test statistics have a chi-square distribution. Outcomes from the Wald test might be misleading if the estimated standard error and the absolute value of the regression coefficients are large. A smaller value for the Wald statistic is produced as a result, which leads to a Type II error (failing to reject the null hypothesis when the alternate hypothesis is true). The Score test is typically used in situations where estimating the unrestricted model is quite problematic relative to estimating the restricted model (Wooldridge, 2002). It measures how far from zero the score function is when estimated at the null hypothesis, i.e. ‘‘only requires estimation under the null’’ (Wooldridge, 2002). For this study, the likelihood ratio (LR) test statistic is used to either reject or fail to reject the null hypothesis. Likelihood ratio tests are easily computed once the estimates for the restricted and unrestricted models are known (Wooldridge, 2002). The likelihood ratio test statistics is defined as

(4.7) $$LR = -2logR = -2(InL_R - InL_{UR})$$

where R is the ratio of the maximum likelihood estimate of the parameters of the restricted model to the maximum likelihood estimate of the parameters of the unrestricted model. Both likelihoods are always positive. The null hypothesis is rejected if the difference between the log-likelihoods exceeds the critical value of chi-squared with the appropriate degrees of freedom (Train, 2003).

4.5 Goodness of Fit Measure

In measuring how well the binary logit model fit the data, the likelihood ratio index, McFadden’s R^2, was used. Other models such as the percent correctly predicted (PCP) or count R^2, percent reduction in error (PRE), expected percent correctly predicted (ePCP) and the pseudo R^2 have also been proposed as a measure of goodness of fit. The likelihood ratio index is defined as (Maddala and Lahiri, 2009):

(4.8) $$McFadden's\ R^2 = 1 - \frac{logL_{UR}}{logL_R}$$

where log L_{UR} and log L_R are the maximum values of the log-likelihood function when maximized with respect to all slope coefficients and restriction(s) respectively.

Now that an explanation of the model used for the study and the method used for estimating and validating the model has been given, the next chapter gives an in-depth explanation of the variables included in the model (how they were measured and their *a priori* expectations). A description of the study area is also presented in the next chapter.

Chapter 5 – Overview of Data Set

5.1 Study Area

5.1.1 Location

The study was conducted in the Bawku West district located in the north-eastern part of the Upper East Region of Ghana. The district stretches over an area of 1,070km^2. The 2010 census approximates the population of the district to be 94,034 with a population density of 87.88 persons per square kilometer. The district constitutes 12% of the entire Upper East Region, and ranks fifth in terms of total land size of the region. Its geographical coordinates are longitudes 0^0 20' and 0^0 35'East of the Greenwich meridian and latitudes 10^0 30' and 11^0 10'North of the equator. The northern section is bounded by the Province of Zabre in neighboring Burkina Faso, on the east by the Bawku Municipality, and on the west and south by the Talensi/Nabdam and Mamprusi Districts respectively. The district is divided into seven area councils as follows; Binaba-Kusanaba town council, Zebilla town council, Sapelliga area council, Gbantongo area council, Tanga-Timonde area council, Tilli-Widnaba area council, and Zongoyire area council. The district capital is Zebilla. Agriculture is the mainstay of the district's economy employing more than 80% of the working population in the district. Major crops cultivated in the district include millet, rice, sorghum and maize.

5.1.2 Climate and Vegetation

The study area falls within the Sudan savanna agro-ecological zone which forms part of the semi-arid areas of Ghana. The area has a unimodal rainy season lasting 4-6 months (from May to October) and a long dry period of 6-8 months (from November to April) in a year. The average annual rainfall for the area varies from 900 mm to 1150 mm and temperatures are high, averaging about 28.5^{o}C annually. The maximum length of growing period for rain-fed crops in the district is less than 60 days (Atta-Quayson, 1995). The White Volta and the Red Volta, run contiguous to the district's eastern and western boundaries. It usually overflows its banks during the rainy season (April-October), which is the major cause of flooding in the area. However, during the dry season the White Volta, Red Volta and other tributaries of the Volta River dries up completely, resulting in severe water shortage. The area is characterized by severe drought during the dry season, particularly from December to March. Average monthly rainfall levels recorded during these periods are below 5 mm. The natural vegetation consists predominantly of short drought and fire-resistant deciduous trees interspersed with open savanna grassland. Some environmentally unfriendly farming practices including land clearing for farming, fuel wood harvesting, overgrazing, annual routine bushfires, harvesting of poles for construction and poor conservatory and animal husbandry practices have led to loss of the vegetative cover in the study area. As a result the organic matter content of soil is generally low averaging less than 1% with frequent deficiency of nitrogen and phosphorus. The soil types of the district are mainly Luvisols, Leptosols, Gleysols and fluvosols.

5.2 Data Source

The nature of the study necessitated the use of only primary data set to achieve the study objectives. The primary data used in this study were obtained from a household survey conducted in the 2007/2008 production season in the Bawku West district of Ghana. Table 2 gives a breakdown of the villages and number of households sampled and interview for the study. A total of 15 out of the 152 villages in the district were sampled and surveyed. Sixteen (16) households were interviewed in each village sampled. Nonetheless, some of the households were omitted due to either data inconsistency or incompleteness. This makes the number of households included in the estimation analysis equal 195 instead of 240. The towns and/or villages sampled fall within the same agro ecological zone (Sudan savanna) with near similar precipitation and temperature pattern. In sampling the villages and households, a combination of both purposive and random sampling techniques were employed respectively. Both qualitative and quantitative data techniques were also adopted for data collection and analysis. At least a village was sampled from each of the seven area councils in the district.

Table 2: Distribution of sampled villages

Area Council	Villages Interviewed	Total No. of Villages	Number of Households Interviewed
Binaba-Kusanaba	Binaba-Natinga		16
	Kusanaba	24	16
Zebilla	Yarigu		16
	Ankpaliga		16
	Zebilla-Natinga	51	16
Sapelliga	Komaka		16
	Kare-Natinga	28	16
	Sapelliga-Zongo		16
Gbantongo	Gbantongo		16
	Kamega Central	17	16
Tanga-Timonde	Tanga Natinga		16
	Tanga-Gbandame	12	16
Tilli-Widnaba	Widnaba-Natinga	8	16
Zongoyire	Zongoyire-Natinga	19	16
	Bulinga		16
Total		152	240

Source: Author's compilation from household survey, 2008

5.3 Data and Survey Description

The household survey generated information on demographic (age, gender, adult literacy, household size, etc.), resource (access to electricity, access to formal/informal credit, etc.), assets (radio and mobile phone ownership, etc.), economic (farm sizes, farm income, etc.), and incidence of different extreme events or shocks (drought, flood and bushfires) on households in the Bawku West district. The survey used both open and closed ended questions to solicit information from respondents. In all 15, coping strategies were identified to be used by households in the event of extreme climatic conditions – five (6) in the event of drought, five (6) in the event of flood and three (3) in the event of bushfires – as listed in Table 3. Data on these coping strategies were gathered qualitatively. The common coping mechanisms most cited in the literature were not presented to each respondent to rank. Instead, informants stated the major strategy they resorted to, to cope with the flood in 2007/2008, and drought period(s) and bushfires within the last three years prior to the study.

In part, this was done to confirm previous literature, and also to identify coping mechanisms specific to the study area. The coping measures (short term) reported may be community-wide decision strategy and or an external assisted strategy rather than a household strategy, i.e. implementation of some the coping measures requires the collective efforts and contribution of the entire community (e.g. construction of or improve drainage system). The strategies could be described as long term or short term strategies. For the purpose of this study, the classification of a strategy as long term or short term could be done interchangeably without any effect on the choice of strategies. Each of these dependent variables was dichotomized with a value of 1 if the household used such a coping strategy, and 0 if otherwise.

To cope with drought conditions experienced annually, households resorted to either planting more trees and cover crops; planting drought resistant or early yielding crops; stored some of their farm produce; planted early before the onset of drought conditions, or did nothing. Likewise, in the event of a flood the coping mechanisms adopted comprised early planting of crops; reliance on aid from government or NGOs; construct or improve the drainage system in the area; desist from farming or building in lowland areas or waterways. Others did nothing in such situations.

Table 3: Household coping mechanism under extreme climatic conditions

Extreme Event	Coping Strategy
Drought	Early planting
	Plant drought resistant and early yielding crops
	Did nothing
	Plant more trees and cover crops
	Irrigation practices
	Food storage
Flood	Early planting
	Stop farming or building in lowland areas or waterways
	Construction of or improve drainage system
	Did nothing
	Ngo or government aid
	Modern building technique
Bushfires	Improve farm maintenance practices
	Fire prevention education
	Did nothing

Source: Author's compilation from household survey, 2008

Bushfires typically occur during the dry seasons when farmers are preparing their land for the next growing period. Their incidence are easily avoidable than any of the extreme events. While some households cope by either improving their farm maintenance practices or educating members of the household and community about the dangers of bushfires, others did nothing. The farm maintenance practices adopted include clearing of weeds and creating fire belts around farm and house. This prevents the spread of fire when preparing the farm land for the next growing season. The 15 coping strategies identified were each coded into a dichotomous variable for the purpose of the model used in analysing the data.

On the other hand, the independent variables are characterized under four broad categories: household characteristics, asset characteristics, resource availability, and other factors. These are presented in Table 4 below.

Table 4: Independent variables used in regression analysis

Household Characteristics	Asset Characteristics	Resource Availability	Other Factors
Age	Radio ownership	Access to electricity	Area Council or Locality
Gender	Mobile phone ownership	Access to formal/informal credit	Source of seed
Household size	Size of farmland	Farmer Based Organization	Effect of climatic event
Literacy level of HH			
Farm income			

Source: Author's compilation from household survey, 2008

5.4 Description and Measurement of Variables

5.4.1 Household Socioeconomic Characteristics

Empirical evidence shows that socioeconomic characteristics of the household, most especially that of the household head, greatly influence household decision to either adopt a particular coping mechanism to climate change or not. Household characteristics included in the model are shown in Table 4 and described below.

Household size was measured by the number of family members living together. The variable captures the effect of the size of a household on the adoption of a particular coping strategy. Empirical literature has shown the influence of household size on farmer's adoption of coping or adaptation measures to be inconclusive. Some studies show that households with large family size are more likely to adopt and use more labor-intensive adaptive or coping measures because they have a large labor pool (Croppenstedt et al., 2003; Deressa et al., 2005; Dolisca et al., 2006; Nyangena, 2007; Anley, et al. 2007; Birungi, 2007). The other assumption is that households with a large family may be forced to divert part of the labor force to off-farm activities to generate more income and decrease the demands on food consumption (Mano and Nhemachena, 2006; Tizale, 2007; Yirga, 2007). Based on the assumptions given, this study expects either a positive or negative influence of household size on the choice of a coping strategy.

A qualitative variable was created for the *gender of household head* variable which takes the value of 1 if the household head is a male and 0 otherwise. Various studies show that the choice of an adaptation or coping strategy was apparently a gender-sensitive decision. On one hand, it is argued that male household heads are relatively risk averse and have more access to information, land and other resources relative to female-headed households (Asfaw and Admassie, 2004; Tenge and Hella, 2004; Bryan et al., 2011) particularly in the developing world hence are more likely to adopt certain practices than female household heads (Marenya and Barrett, 2007). According to De Groote and Coulibaly 1998, and Quisumbing et al. 2011, African women have reduced access to critical resources (land, cash and labor), which often undermines their ability to carry out labor-intensive agricultural innovations. On the other hand, some literature has indicated a relatively higher level in adopting certain coping measures by female-headed households (Newmark et al., 1993; Burton et al., 1999; Dolisca et al., 2006; Nhemachena and Hassan 2007; Bayard et al., 2007). For the purpose of this study, it assumed that there is no significant difference in the gender of household heads in choosing a particular coping method.

The *age of the household head* was grouped into 3 categories: 19-39 years, 40-69 years, and greater or equal to 70 years. Each category was separately coded as a dichotomous variable, taking the value of 1 if the age of household head is within that range, and 0 otherwise. The age variable could represent the farming experience of the household head. Like most other variables, empirical literature on the influence of age has been varied. While some reveal a positive significant effect of age on adoption (Okoye, 1998; Bayard et al. 2007; Deressa et al., 2005), others have shown otherwise (Featherstone and Goodwin, 1993; Lapar and Pandely, 1999; Burton et al., 1999; Dolisca et al., 2006; Nyangena, 2007; Anley et al., 2007, Hassan and Nhemachena, 2008). Other studies have also shown age as significant variable on household's adoption decision (Adesina and Forson, 1995; Thacher et al., 1997; Anim, 1999; Zhang and Flick, 2001; Bekele and Drake, 2003). It is therefore hypothesized that age of household head has either a positive or a negative influence on the choice of coping strategies to climate change by households.

The *literacy level* of household head could be captured in various ways. The first is the maximum number of years of school attended by the household head. Another is to use a qualitative variable which takes a value of 1 if household head attended any school and 0 otherwise. However, a dummy variable of 1 if head of household is literate and 0 otherwise was used for this study. The expectation is that the literacy level of household head significantly influences adoption decisions on certain adaptation or coping measures as has been shown empirically (Lin, 1991; Adesina and Forson, 1995; Daberkow and McBride 2003; Glendinning et al., 2001; Maddison, 2006; Dolisca et al., 2006; Anley et al., 2007; Tizale, 2007; Ibrahim et al., 2011).

The expenditure of each household was used as a proxy for household *farm income* and measured in Ghana Cedis (GH¢). This variable is a measure of wealth, and reflects the ability of a household to cope with risk. Some of the early studies show a positive correlation between income and adoption (Franzel, 1999; Knowler and Bradshaw, 2007; Ibrahim et al., 2011). This study postulates that farm income increases household’s ability to adopt certain coping strategies to climate change.

5.4.2 Asset Characteristics

The *size of farm land* is an important asset in rural households and is a function of the available economic resources to the household. The farm size variable is defined as acres of farmland. Following the results from Daberkow and McBride, 2003, there may be a critical lower limit on farm size that prevents smaller farms from adapting given the uncertainty and the fixed transaction and information costs associated with innovation. Households with smaller farms are less likely to adopt innovations with large fixed transaction and/or information costs. However, a later study by Bradshaw et al., 2004 contradicted the findings of Daberkow and McBride, 2003, showing that farm size had both negative and positive effects on adoption. The expected result of this study is therefore an empirical question.

Ownership of radio and *ownership mobile phone* is each dummied taking a value of 1 if household have ownership of such asset and 0 otherwise. Households that possess a radio or mobile phone will have a more timely access to information on climate situation of their locality and improve technologies or practices available for mitigation. As such the study postulates a positive relationship between the ownership of radio or mobile phone and household’s adoption decision.

5.4.3 Resource Availability

The study assumes that any household head that is member of any Farmer Based Organization (FBO) will have *access to extension* services. This is measured in the form of a qualitative variable which takes a value of 1 if household head is member of an FBO, and 0 otherwise. Access to information on new and improved agricultural practices, is critical to the ability of farmers particularly in developing nations to cope with climate change and variability. Such information is easily accessible to farmers through extension services. Some empirical research indicates a positive relationship between extension education and adoption behaviors of farmers (Anley et al., 2007; Nhemachena and Hassan, 2007; Yirga, 2007; Fosu-Mensah et al., 2010). This study proposes that membership in an FBO gives access to extension information and increases the chances of a farmer adopting certain coping strategies to climate.

In low-income areas such as Bawku West District, the ability of households to adopt certain cost intensive climate change coping mechanisms – purchase of improved crop varieties, fertilizers and relocating to different farm sites due to flood – will be contingent on the availability and accessibility of credit facilities. Several studies postulate a positive relationship between access to credit and adoption behavior (Napier 1991; Saín and Barreto 1996; Kandlinkar and Risbey, 2000; Caviglia-Harris 2002; Pattanayak et al., 2003; Nhemachena and Hassan, 2007; Ibrahim et al., 2011; Gbetibouo 2009). Similarly, this study also hypothesizes a positive relationship between access to formal/informal credit and adoption. A qualitative variable taking the value of 1 if a household head has *access to formal/informal credit* and 0 otherwise was used as a measure of this variable.

5.4.4 Other factors

Few studies have investigated the influence of source of seed for planting on the choice of climate change coping strategies. If a household use own seed for planting, the value 1 is assigned and 0 if otherwise, to capture to the *source of seed for planting* variable. It is anticipated that depending on the source of seed for planting by a household, it would be likely to adopt certain coping measures or not. The direction of influence is however uncertain.

The seven area councils are grouped under four variables: *Area BZ, Area SG, Area TT* and *Area Z.* These are qualitative variables which take on the value of 1 if household is located within Binaba-Kusanaba and Zebilla for Area BZ, Sapelliga and Gbantongo for Area SG, Tanga-Timonde and Tilli-Widnaba for Area TT, Zongoyire for Area Z and 0 if otherwise. The level of precipitation and temperature among towns in the district only differ slightly. Hence, these variables (Area BZ, Area SG, Area TT and Area Z) are introduced to capture all elements that vary among the various area councils which cannot be explicitly included in the model such as temperature, precipitation and other environmental or geographic factors. The direction of influence on household adoption decision is ambiguous due to the differences in magnitude such factors.

Households that reported to be affected by climatic events do not correspond to households who actually experienced the impact or effect of such climatic event. Some households indicated to have experienced the effect of flood, drought or bushfires but reported were not affected by such conditions. To correct for any non-item response bias, the effect variable is included in the binary logit model. The *impact* variable takes a value of 1 if households experienced the impact of climatic event (flood, drought, and bushfires) and 0 if otherwise. A positive relationship between effect and household adoption decision is hypothesized for this study.

Figure 2: Example of questions on affected by and impact of climatic conditions

8a. Has your household been affected by flooding?

☐ Yes

☐ No

8b. If yes, explain how you were affected by the recent floods (effects of flood).

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

With the understanding of the variables included the logit regression model established, the following chapter will discuss the results for the study.

Table 5: Description and measurement of explanatory variables used in regression model

Variables	Description and Measurements	Expected sign
Household Characteristics		
Age X	Takes the value of 1 if age of household head is within 19-39 years and 0 otherwise	+/-
Age Y	Takes the value of 1 if age of household head is within 40-69 years and 0 otherwise	+/-
Age Z	Takes the value of 1 if age of household head is greater than or equal 70 years and 0 otherwise	+/-
Gender	Takes the value of 1 if the household head is a male and 0 otherwise	+/-
Household size	Number of family members living together	+/-
Literacy level	Takes a value of 1 if head of household is literate and 0 otherwise	+
Farm income	Measured in Ghana Cedi (GH¢)	+
Asset Characteristics		
Radio ownership	Takes a value of 1 if household have ownership of radio and 0 otherwise	+
Mobile phone ownership	Takes a value of 1 if household have ownership of mobile phone and 0 otherwise	+
Size of farmland	Acres of farmland	+/-
Resource Availability		
Access to electricity	Takes the value of 1 if a household head has *access to electricity* and 0 otherwise	+
Access to formal/informal credit	Takes the value of 1 if a household head has *access to formal/informal credit* and 0 otherwise	+
Farmer-to-farmer extension	Takes a value of 1 if household head is member of an FBO and 0 otherwise	+
Other Factors		
Area council BZ	Takes a value of 1 if household is located within Binaba-Kusanaba and Zebilla area councils and 0 otherwise	+/-
Area council SG	Takes a value of 1 if household is located within Sapelliga and Gbantongo area councils and 0 otherwise	+/-
Area council TT	Takes a value of 1 if household is located within Tanga-Timonde and Tilli-Widnaba area councils and 0 otherwise	+/-
Area council Z	Takes a value of 1 if household is located within Zongoyire area council and 0 otherwise	+/-
Effect	Takes a value of 1 if household experienced any effect from drought, flood or bushfires and 0 otherwise	+
Source of seed	If household head use own seed for planting, the value 1 is assigned and 0 otherwise	+/-

Chapter 6 – Results and Discussion

6.1 Introduction

This chapter presents in detail the results of the study. A description of the socio-economic profile of respondents in the study area, together with the proportion of households severely affected by shock(s) from climate change (drought, flood and bushfires) is presented in Section 6.2. In subsequent sections, an in-depth discussion of each of the extreme events is presented focusing on: the effects of shock(s) on the livelihood of households, the adjustments households made in other to cope with such situations and an estimation of factors that influence the adoption of given adjustments or coping measures by households. Sections 6.3 and 6.4 discuss the two main agro-climatic conditions: flood and drought. The final section discusses coping strategies for bushfires.

6.2 Socioeconomic Profile of Study Area

As noted early on, socioeconomic characteristics of households are hypothesized to have significant influence on adoption decisions. This sub-section takes a brief look at the socio-economic profile of the respondents interviewed for the study. Male household heads constitute 86.7 percent of the respondents sampled and interviewed. Out of the 80 percent who are married, 77.6% are monogamous marriages, and the remaining 22.4% are polygamous marriages. Table 6 shows selected household demographics such as age, income, land size, household size, etc. The age distribution of respondents depicts a rightward or positively skewed normal distribution. Fifty-five percent of household heads fall within the age group of 40 to 69 years, 30 percent are between the ages of 19 to 39 years, and more than 15 percent are 70 years and above. The literacy level of sampled respondents is slightly higher than the regional average, with 25.6 percent capable of reading and writing.

Table 6: Selected household demographics

	Percent (%)	Average
Age		
19 to 39 years	30.3	
40 to 69 years	53.3	
70 years >	15.9	
Material for wall		
Mud/mud bricks	90.2	
Cement/sandcrete	8.8	
Material for roof		
Mud	4.1	
Thatch	58	
Wood	2.6	
Metal sheet	33.7	
Household size		5.86
Income		$2844 (2008USD)
Land size		7.76 acres
Literate	25.6	
Livestock ownership	88.7	
Access to extension	23.6	
Access to electricity	12.8	

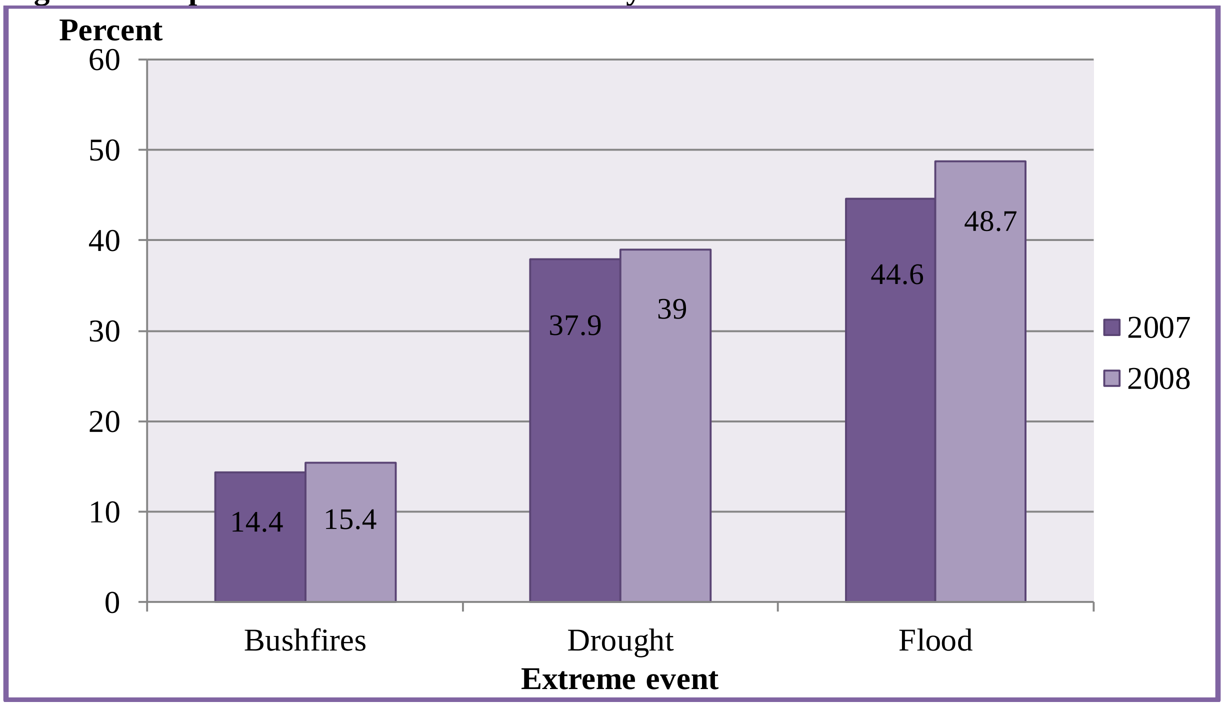
Source: Author's compilation from the household survey, 2008
Note: N = 195

Crop, livestock and fish farming are the primary source of livelihood for more than 85 percent of sampled households. This affirms the fact that agriculture remains the dominant economic activity in the district. The size of land owned by households ranges from 0.5 to 40 acres, with an average land holding of 7.76 acres. A majority of households (88.7%) owned livestock, probably to plough on farms or sever as a source of food security, collateral for loans and or prestige. The average expenditure of households, used as a proxy for income is GH¢3009, almost $2844 (2008USD) per year. The result indicates that, on average, more than half of households live above the poverty line of $1.50 a day. This might not be the case, since data on income show few outliers that weighed heavily on the average income level. Income levels are heavily concentrated at the right tail of a normal distribution curve. With this level of income and the predominant agricultural economy of the study area, it is no surprise that only 13 percent of households have access to electricity. Access to formal/informal credit and farmer-to-farmer extension service are also limited to only 38 percent and 24 percent of sampled households, respectively.

The data for the study were collected in the aftermath of a prolonged drought followed by a devastating flood condition in the district and the entire Upper East region, which occurred during the 2007 and 2008 production seasons. These conditions brought severe economic hardship on the people and more than 61 percent indicated suffering severe food shortage as a result. Most attributed the severe food shortage or inability to meet food needs to poor harvest resulting from pest/disease (10.9%) and extreme climatic conditions (30.7%). A high food price was also a major contributing factor, as indicated by 38.7% of respondents. Materials for wall and roof of buildings are predominantly made of mud/mud bricks (90.2%) and thatch (58%) respectively. The fragile nature of these building materials leave households at the mercy of the slightest climatic extreme causing the collapse of either all or part of their buildings.

Given that the field research for the study was conducted in the aftermath of the 2007/2008 extreme climatic events, respondents were asked whether their households were impacted in any way. Figure 3 shows an increasing trend of households affected by extreme climatic conditions. Bushfires affected 14.4% of respondents in 2007 and 15.4% in 2008. The proportion of drought affected households appreciated slightly from 37.9% in 2007 to 39% in 2008. It is not surprisingly that more households felt the impact of the flood in both years – 44.6% in 2007 and 48.7% in 2008 – than any of the other climatic conditions. The incidence of the flood came as unexpected and most communities were not prepared for such worst case scenario.

Figure 3: Proportion of households affected by extreme climatic conditions in 2007/2008



Source: Author's compilation from household survey, 2008
Note: N = 195

The subsequent sections discuss the effect of climate change on the sampled households, the main coping mechanisms used for adjusting to climate change, and the estimates from the binary logit regression for each of the coping measures households use. Recall that, for the purpose of this study, there is no distinction between coping and adaption measures. The two terms are used interchangeably throughout the discussion unless otherwise stated. Coping strategies identified could be placed under two distinct categories: inward-looking and outward-looking. Inward-looking strategies require households to rely on their internal resources and outward-looking, on external resources such as community, government and or non-governmental support (Mingione, 1987). The implementation of either type of strategy might require either monetary or non-monetary resources (Snel and Staring, 2001).

6.3 Coping Strategies for Floods

Table 7 shows the effect of flood on the 91 sampled households affected by flood. More than 36 percent reported destruction of their farm or farm produce including maize, millet, rice, sorghum and cowpea. Whiles some farmers reported that their harvested crops (including seeds) were washed away by the flood others had their farms flooded and crops that were still not harvested got destroyed. Crops that were able to withstand the flood produced poor yields as indicated by 5.5% of households. The flood in 2007 revealed the vulnerability of buildings of households which are primary constructed with weak building materials like mud and thatch. All or part of buildings owned by twenty two percent of respondents collapsed. The number of rooms of partly damaged homes ranged from one to six. This rendered some of the inhabitants' homeless for a period, but for the intervention of government and non-governmental organizations.

Table 7: Effects of flood on households

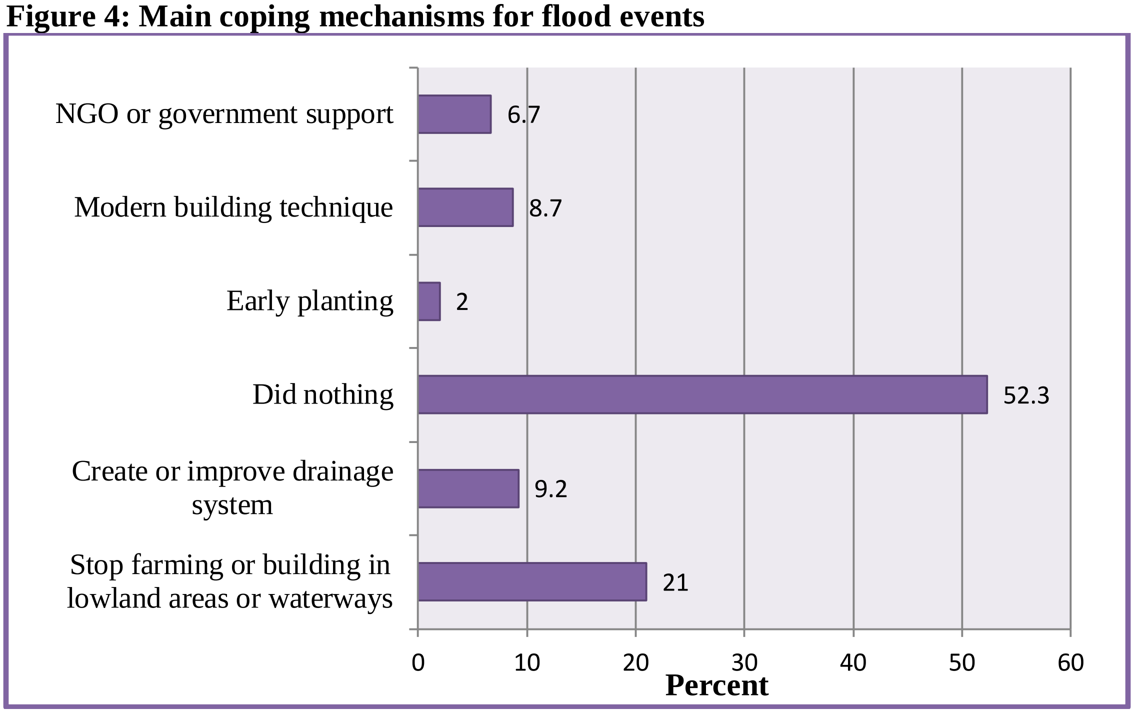
	Percent
Destroyed crops only	36.3
Decline in crop yield	5.5
Destroyed house only	22.0
Destroyed crops and livestock	3.3
Destroyed crops and house	17.6
Destroyed livestock and house	3.3
Destroyed crops, livestock and house	3.3
Food shortage	8.8

Source: Author's compilation from household survey, 2008
Note: N = 91

For 17.6 percent of households, both their crops and homes got destroyed. Three percent had both their livestock and crops destroyed by the flood. The impact of the flood was quite distressing on 8.8 percent of households which experienced severe food shortage. Others (3.3%) had a triple impact of flood on their livelihood: destruction of crops, livestock and buildings.

From a much more heuristic view, flood effects on households could have two distinct impacts. Initial impact could be a reduction in food production derived from the decline in environmental quality and this could cause serve food shortage or starvation among farming communities. The second impact could be a rural-urban migration scenario which could lead to a reduction in agricultural labor in such rural communities. Floods decrease the quality of farmlands in sustaining subsistence agriculture; as a result productivity and farm income decline. Households begin to seek other non-farm income sources which are mostly only available in urban centers.

Figure 4: Main coping mechanisms for flood events



Source: Author's compilation from household survey, 2008
Note: N = 195

To cope with flood situations, households have developed some long term (proactive strategies) and short term (reactive strategies) measures, some of which are inward-looking or outward-looking and might require monetary or non-monetary resources. As shown in Figure 4, close to 16 percent of respondents relied on external factors such as governmental or non-governmental aid (6.7%) and external support to create new or improve existing drainage system (9.2%). Others have changed their farm management practices by planting early (2%) in the production season or stop farming in lowland areas (21%). Still, a majority (52.3%) of respondents affected by flood indicates they did nothing to cope with the situation.

6.3.1 Factors Influencing the Adoption of Coping Strategies for Floods

Tables 8 and 9 show the parameter estimates and marginal effects, respectively, from the binary logit regression (BLR) for each of the coping strategies for floods. Five binary logit estimations are presented. For simplicity and ease of discussion, the various models are described as Model 1 (model with 'stop farming in lowland areas' as dependent variable), Model 2 (model with 'improve drainage system' as dependent variable), Model 3 (model with 'did nothing' as dependent variable), Model 4 (model with 'modern building technique' as dependent variable) and Model 5 (model with 'NGO or government aid' as dependent variable). Efforts were made to include the same variables for each of the models estimated. However, the problem of partial separation was encountered in estimating Models 4 and 5. The access to electricity, effect of flood and area TT (Tanga-Timonde and Tilli-Wadnaba) variables correctly predicted the dependent variable in Model 5 and was subsequently dropped. Likewise, in model 4 the area TT (Tanga-Timonde and Tilli-Wadnaba) variable was again dropped due to partial separation. The number of explanatory variables included in Models 4 and 5 were 16 and 14, respectively instead of 17 in the other models. The likelihood ratio statistic for all the models are highly significant, an indication of their strong explanatory power.

Evidence from the model results as shown in Tables 8 and 9 suggest that, the set of significant explanatory variables varies across the different coping measures in terms of significant levels and signs. The study found out that access to electricity is significant and positively influence adopting improve drainage system but negatively influenced decision to stop farming in lowland areas in other to cope with floods. This implies that the probability of households with access to electricity to select an improve drainage system as a coping measure to floods is 0.142 greater than households without electricity. Also the probability to stop farming in lowland areas is 0.251 lower for households with access to electricity than households without access to electricity.

In terms of membership with an FBO, the results revealed a negative and positive significant influence in models 3 and 4, respectively. No adaptation is negatively affected if household head is a member of an FBO. Knowledge transfer, information sharing through extension and collective support obtained from being a member of an FBO enhances adaptability of members to floods. Being a member of an FBO decreases the likelihood of no adaptation by 0.146 but increases the probability of resorting to modern building techniques by 0.123.

Seed source is a significant determinant of no adaptation, modern building techniques and reliance on NGO or government aid. Farmers that depend on government or NGOs as their major seed supplier for planting are likely to do nothing in the event of floods. Also, the probability of such households depending heavily on government support during floods declines by 0.07. Household heads within the ages of 40-69 years are less likely to depend on external support compared to household heads between the ages of 19 to 39 years in order to cope with floods. The result shows a negative significant effect of age range 40-69 years on the decision to depend on NGO or government aid for adaptation. The probability of non-dependence on external support decrease by 0.07 for farmers aged between 40-69 years than those aged between 19-39 years.

Large households have a relatively high burden in meeting nutritional and basic needs of all members due to food shortage and decline in agricultural productivity associated with floods. There is a high tendency for such families to depend on NGO or government support to cope with floods as shown by the results. Household size positively and significantly influences dependence on external support to cope with floods and the probability for such dependence increases by 0.018 with one additional household member.

As expected, income negatively influences the decision of no adaptation and dependence on external support. On the other hand, decision to stop farming in lowland areas has a positive significant relationship with income. Wealthier households mostly have large amount of assets in the community and are therefore more likely to find some measures to mitigate the effect of climate change on their assets. Also, given that the decision to stop farming in lowland areas is risky, only wealthier households are likely to adopt such measures.

Some observable and unobservable characteristics of the different area councils are expected to affect adoption decisions. As indicated by the results, households in area BZ (Binaba-Kusanaba and Zebilla) are more likely to adopt improve drainage system and depend on NGO or government support but less likely to do nothing in the event of flood compared to households in area SG (Sapelliga and Gbantogo). Living in Binaba-Kusanaba and Zebilla increase the probability of selecting improve drainage system or external support by 0.115 and 0.07 respectively.

Table 8: Parameter estimates of logit model of coping strategies for floods

Variables	Stop farming in lowland areas		Improve drainage system		Did nothing		Modern building technique		Ngo or government aid	
	Coeff.	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*
Literacy	0.706	0.493813	0.361	0.874955	-0.436	0.437836	-0.874	0.89932	1.152	1.183745
Radio ownership	-0.257	0.439398	0.357	0.778364	0.324	0.368121	-0.295	0.825807	-0.120	0.780916
Mobile phone ownership	-0.098	0.541141	0.103	0.801638	0.257	0.444027	0.353	0.755904	-1.705	1.394914
Access to electricity	**-1.825****	0.820502	**2.403*****	0.788052	-0.587	0.54863	1.935	1.496268	----	----
FBO	0.301	0.503388	0.023	0.799559	**-0.738***	0.441089	**2.411*****	0.988277	0.959	1.121783
Seed source	0.647	0.47239	0.134	0.741915	**-0.598***	0.367939	**3.080****	1.505774	**-1.937****	0.842661
Age X	0.324	0.691655	0.922	1.200926	-0.243	0.533768	1.916	1.501906	-0.400	1.125439
Age Y	0.530	0.63878	0.856	1.024132	-0.445	0.473777	1.162	1.472121	**-1.736***	1.015814
Gender	0.997	0.750646	-0.596	0.967468	-0.355	0.542075	-1.703	1.261651	0.506	1.581999
Household size	-0.118	0.092213	0.078	0.145645	-0.082	0.072894	0.046	0.176836	**0.449*****	0.154331
Income	**1.708*****	0.580673	-0.494	0.601151	**-0.839****	0.386604	1.516	1.004669	**-1.586****	0.891688
Area Z	-0.896	0.79789	1.423	1.459715	-0.354	0.572868	1.556	1.410511	1.001	1.136271
Area BZ	-0.077	0.5156	**1.947****	0.842537	**-0.956****	0.415665	0.071	1.032388	**1.771***	1.047464
Area TT	0.253	0.587312	1.544	1.127336	-0.039	0.487869	----	---	---	----
Effect	**-0.850****	0.423238	**-2.025*****	0.839391	**-0.599***	0.344366	**3.965*****	1.28723	---	----
Access to credit	-0.010	0.437744	-0.503	0.68924	-0.391	0.352209	0.952	0.935425	0.408	0.871924
Farm size	-0.053	0.039473	-0.042	0.061596	**0.059****	0.029422	0.010	0.077248	**-0.250****	0.118431
Constant	-7.190	1.930971	-2.761	2.164939	4.737	1.3095	-14.88	4.213578	0.807	2.672622
No observation	195		195		195		195		195	
Log likelihood	-83.407		-40.994		-113.377		-32.1998		-27.7109	
LR chi square	31.08		38.07		43.34		51.03		34.74	
Pseudo R2	0.1571		0.3171		0.1604		0.4421		0.3853	
Prob>chi 2	0.0195		0.0024		0.0004		0.0000		0.0016	

Source: Author's compilation from household survey, 2008

*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

Table 9: Marginal effects of logit model of coping strategies for floods

Variables	Stop farming in lowland areas		Improve drainage system		Did nothing		Modern building technique		Ngo or government aid	
	dy/dx	*Std. Err*	*dy/dx*	*Std. Err*	*dy/dx*	*Std. Err*	*dy/dx*	*Std. Err*	*dy/dx*	*Std. Err*
Literacy	0.097	0.066855	0.021	0.051999	-0.086	0.086206	-0.044	0.044832	0.046	0.048167
Radio ownership	-0.035	0.060302	0.021	0.046079	0.064	0.072645	-0.015	0.041919	-0.004	0.031778
Mobile phone ownership	-0.013	0.07446	0.006	0.047456	0.051	0.087979	0.017	0.038308	-0.069	0.056546
Access to electricity	**-0.251****	0.108974	**0.142*****	0.043898	-0.116	0.107827	0.098	0.075247	----	----
FBO	0.041	0.069001	0.001	0.047375	**-0.146***	0.085459	**0.122*****	0.04535	0.039	0.04549
Seed source	0.089	0.064202	0.007	0.043993	**-0.118***	0.071339	**0.156****	0.073705	**-0.078****	0.033686
Age X	0.044	0.094998	0.054	0.071022	-0.048	0.105877	0.097	0.074214	-0.016	0.045745
Age Y	0.072	0.087389	0.050	0.060564	-0.088	0.093386	0.059	0.074135	**-0.070***	0.040704
Gender	0.137	0.101937	-0.035	0.057456	-0.070	0.107266	-0.086	0.062968	0.020	0.064581
Household size	-0.016	0.01256	0.004	0.008594	-0.016	0.014322	0.002	0.008969	**0.018*****	0.005745
Income	**0.235*****	0.075515	-0.029	0.035633	**-0.166****	0.073679	0.077	0.049727	**-0.064***	0.03585
Area Z	-0.123	0.108882	0.084	0.086282	-0.070	0.113389	0.079	0.070527	0.040	0.046357
Area BZ	-0.010	0.070959	**0.115****	0.048521	**-0.190****	0.078291	0.003	0.052544	**0.072***	0.0423
Area TT	0.034	0.080746	0.091	0.066852	-0.007	0.09694	----	---	---	----
Effect	**-0.117****	0.056348	**-0.119****	0.050299	**-0.119***	0.066601	**0.201*****	0.059204	---	----
Access to credit	-0.001	0.060245	-0.029	0.040793	-0.077	0.069155	0.048	0.046683	0.016	0.035347
Farm size	-0.007	0.00536	-0.002	0.003647	**0.011****	0.005631	0.0005	0.003936	**-0.010****	0.004616
No observation	195		195		195		195		195	

Source: Author's compilation from household survey, 2008
*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

Large farm size positively influences no adaptation with a probability of 0.011and negatively influences dependence on external support with a probability of 0.010 with an additional unit of farmland.

The results show that adoption decision is strongly influenced when households experienced the impact of floods (such as destruction of crops, livestock or house). Surprisingly, the probabilities of adopting improve drainage system and discontinue farming in lowland areas falls if households experienced any effect from flood by 0.117 and 0.119 respectively. Nonetheless, the probability of selecting modern building techniques as an adaptive measure to floods increased by 0.202 if households were impacted or experienced a loss of some sort caused by floods. It may not be possible to stop farming or improve drainage without moving.

6.4 Coping Strategies for Drought

The section presents the effect of drought on households, the main coping mechanisms to drought conditions and parameter estimates from the BLR of factors influencing the adoption of coping strategies for drought.

Some respondents (73) recounted having experienced several impacts from drought as shown in Table 10. Poor yield or harvest was reported by 67 percent of the 73 households affected by drought. Most farmers in the district usually cultivate their land after the first rain. A delay in the rains as a result of drought resulted in poor crop yield and harvest. Grasslands for livestock grazing got dried up which caused the death of several animals. Likewise, some surveyed households indicated their farm crops wilted and subsequently dried up. Nearly three percent of drought affected households encountered severe water shortage since most water sources (rivers and streams) got dried up.

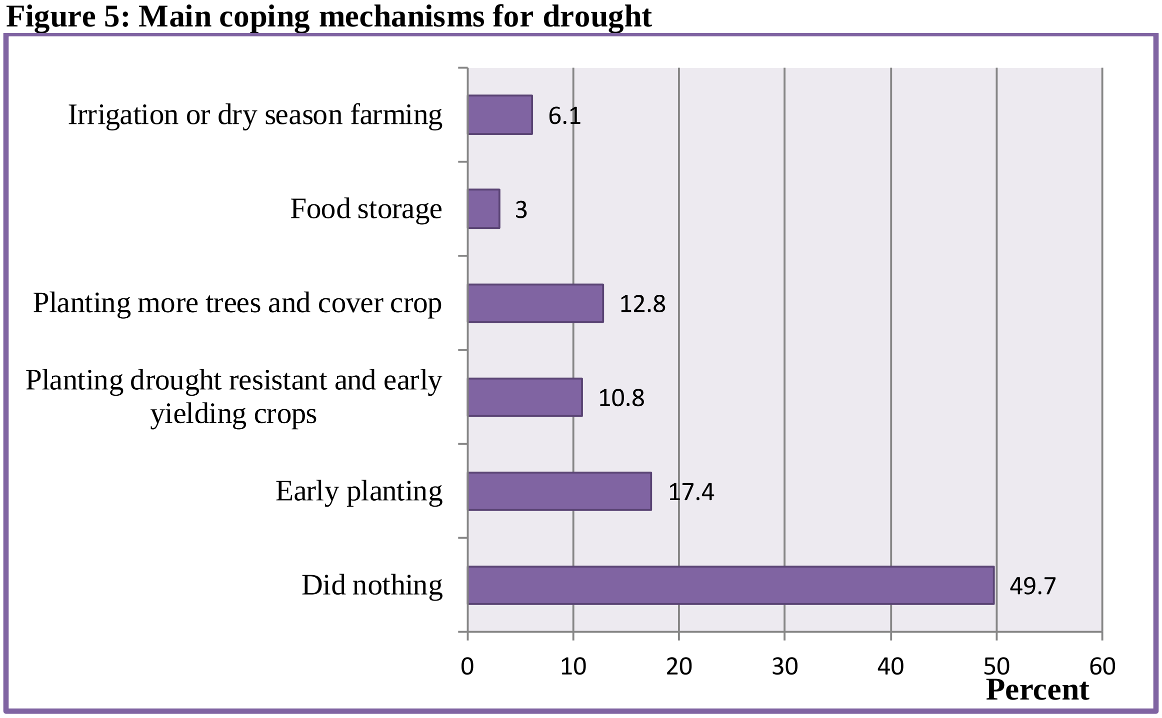
Table 10: Effect of drought on households

	Percent
Poor yield or harvest	67.1
Destruction of crops and livestock	30.1
Water shortage	2.8

Source: Author's compilation from household survey, 2008
Note: N = 73

The occurrence of drought conditions is seen as a "normal" phenomenon in the district due to the climatic pattern there. However, the intensity of the drought periods differ yearly and households' have in the course of time developed measures to enable them not only cope with such situation but also adapt to its impact. Six coping strategies were identified as households' responses to drought events in the Bawku West district.

Figure 5: Main coping mechanisms for drought



Source: Author's compilation from household survey, 2008
Note: N = 195

As illustrated in Figure 5, these strategies include irrigation or dry season farming (6.1%), food storage (3%), planting more trees or cover crops (12.8%), planting drought resistant or early yielding crops (10.8%), early planting (17.4%) and no adaptation (49.7%). These strategies predominantly require the reliance on households' internal resources or factors as opposed to seeking external support.

Irrigation and tree planting are long-term measures for adaption to drought. Though the latter is largely agreed by in the science community to not be a major panacea to mitigating drought since doing the opposite (mismanagement of land resource) is not the main cause of climate change in the Sahel regions. And yet, many empirical studies on climate change adaptation including this study, still shows tree planting as a major coping or adaptation measure among households in developing regions. Tschakert et al. (2009), described this as a 'received wisdom which has dominated popular imaginations.' It has become extremely difficult in getting this persisted notion out of the minds of people. Nonetheless, tropical oceans and sea surface temperature anomalies that occurs as a result of anthropogenic emissions from industrialized nations have been identified as major drought causing factors (Tschakert et al., 2009).

According to the results, a large number of households (49.7%) had no adaptation strategy to drought. While this might seem high, a number of factors could be attributed to this result. First off, dry periods (or drought periods) for the region span from November to April (or November to June in extreme drought situations) annually and their occurrences are seen as normal circumstances. Most households have integrated the other coping strategies into their normal daily activities and don't see them as otherwise. For others, drought conditions have some spiritual inclination and their only coping measure is to pray to God. They offer sacrifices to deities during certain times of the year for protection.

6.4.1 Factors Influencing the Adoption of Coping Strategies for Drought

As presented in subsection 6.3.1, the five BLR models for the coping strategies for drought shown in Tables 11 and 12 are assigned as Model 6 (model with ‘early planting’ as dependent variable), Model 7 (model with ‘planting drought resistant or early yielding crops’ as dependent variable), Model 8 (model with ‘did nothing’ as dependent variable), Model 9 (model with ‘trees and cover crops planting’ as dependent variable), and Model 10 (model with ‘irrigation practices’ as dependent variable). The likelihood statistics indicates a high level of significance for all the models, as such all the models have a strong explanatory power. Here again, the problem of partial separation was encountered in estimating Models 7 and 10. The gender variable was dropped from Model 7 and the area BZ variable also dropped from Model 10.

The results from the binary logit regression model for coping strategies for drought show that most of the explanatory variables influence adaptation to drought situations. Exceptions are radio ownership, mobile phone ownership and access to electricity, that have no significant influence on adoption decisions. It is difficult to draw any inference, since access to information (which is mostly accessible through the radio and mobile phone in rural areas) position rural poor to better adapt to climate change.

A key result is the effect of literacy on adaptation to climate change, as literacy promotes the use of early planting measures to cope with drought. This shows the importance of human capital for the ability to cope and adapt to climate which is in sync with T. W. Schultz’s (1954) assertion of the importance of human capital for agricultural productivity. Household heads that are able to read and write have a 0.167 probability higher than those who cannot read or write in adopting early planting strategy.

Women in Africa are primarily responsible for food security, provision of water and energy for household use. As such female household head are more likely to engage with at least one coping measure to climate change. This could reduce the time burden needed to carry out responsibilities (such as the time it takes to get clean and portable water) as a result of drought. However, the estimates show that female household heads are more likely to result no adaptation to cope with drought. Being male reduces the probability of doing nothing by 0.193. The probable reason could be that females have relatively limited access to information, resource and are less educated. The ability to adopt any of the other coping strategies for drought requires these critical resources.

Household heads belonging to farmer-based organizations (FBOs) are more likely to plant trees or cover crops to adapt to drought. Likewise, families with large size are more likely to use trees and cover crops planting as a coping measure to drought. This adaptation measure is labor intensive, requiring lots of man-hours to be an effective coping mechanism. Also large household size decrease the likelihood of adopting drought resistant or early yielding crops as a coping option to drought, as the results show a negative significant relationship between household size and planting drought resistant crops. Increasing the number of household by one decreases the probability of adopting drought resistant crops by 0.018 but increases the probability of adopting tree or cover crops planting by 0.028 to adapt to drought.

It is interesting to note that seed source has a significant effect on adoption decisions. Early planting and planting of trees or cover crops respectively, are positively and negatively influenced by the source of seeds for planting. If the farmer depended largely on his own seed for planting, the likelihood of adopting early planting increased by 0.166 and the likelihood of selecting tree or cover crops planting strategy reduced by 0.137.

High income households are less likely to adopt early planting measures, but more likely to adapt to drought events by planting drought resistant or early yielding crops. The latter is relatively a more effective measure and this could explain the reason why high income households opt for that option to cope with drought.

Access to credit is strongly associated with the use of early planting measures to cope with drought. Having access to credit increased the probability of selecting early planting strategy by 0.128. Surprisingly, the coefficient of farm size is significant and positive for no adaptation but negative for tree or cover crops planting. This implies that households with large farm size will more likely do nothing to adapt to drought, but smaller sized households have higher probability to plant trees or cover crops as an adaptive measure to drought. The probability of selecting tree or cover crops planting strategy declined by 0.036 whiles the probability of selecting no adaptation rose by 0.022 with a one acre addition of farmland.

Area council TT (Tanga-Timonde and Tilli-Wadnaba) is the only variable that significantly influenced the adoption of irrigation practices. The probability of adopting irrigation practices increased by 0.115 for farmers living in area TT (Tanga-Timonde and Tilli-Wadnaba) than for farmers living in area BZ (Binaba-Kusanaba and Zebilla). Likewise, there is a positive correlation between the area of residences and the choice of tree or cover crops planting as an adaptation measure to drought. The likelihood of households severely impacted by drought to adopt the planting of drought resistant or early yielding crops strategy to cope with drought increased by 0.074. The results show a positive significant relationship between adoption of drought-resistant crops and the impact of drought on households.

Table 11: Parameter estimates of the logit model of coping strategies for drought

Variables	Early Planting		Drought resistant		Did nothing		Tree planting		Irrigation Practices	
	Coeff.	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*
Literacy	**1.454*** **	0.549619	-0.254	0.7388	-0.474	0.443038	0.232	0.798395	0.214	0.893684
Radio ownership	-0.600	0.515208	0.881	0.786563	0.345	0.367095	-0.317	0.645582	-0.691	0.836753
Mobile phone ownership	0.306	0.557935	-0.877	0.772346	0.095	0.441475	0.275	0.834112	0.172	0.856458
Access to electricity	-1.258	0.804949	0.030	1.038706	-0.022	0.53897	1.390	0.942735	0.124	1.318124
FBO	-0.818	0.650084	0.040	0.870321	0.099	0.450486	**2.017** **	0.853565	-0.423	1.213049
Seed source	**1.447** **	0.599176	1.477	0.963948	-0.607	0.380041	**-2.031*** **	0.711911	1.900	1.241503
Age X	0.426	0.741309	**2.520** **	1.389018	-0.860	0.552351	0.300	1.015055	15.94	1364.823
Age Y	0.066	0.69992	2.059	1.323442	-0.682	0.492833	-0.847	0.872027	15.37	1364.823
Gender	-0.682	0.672915	----	**---**	**-0.978***	0.539844	0.965	1.177802	1.237	1.54205
Household size	-0.150	0.107201	**-0.314** **	0.154882	0.022	0.070407	**0.421** **	0.139054	0.089	0.149581
Income	**-0.741***	0.45654	**2.143** **	1.11184	0.334	0.356072	-0.629	0.72869	0.030	0.739583
Area BZ	-0.331	0.574432	18.02	2593.97	**-1.265*** **	0.433023	**3.122*** **	1.084247	---	---
Area Z	-0.892	0.808546	15.84	2593.971	-0.761	0.56786	**2.471** **	1.28093	1.675	1.092793
Area TT	-0.167	0.616252	16.14	2593.971	-0.740	0.500838	**2.041***	1.257201	**2.474** **	1.095376
Effect	-0.008	0.494542	**1.220***	0.711347	-0.449	0.370714	-0.538	0.688854	1.058	0.887791
Access to credit	**1.119** **	0.475807	0.238	0.714363	-0.511	0.360467	-0.842	0.71782	1.228	0.833283
Farm size	0.032	0.034338	-0.116	0.114576	**0.111*** **	0.035186	**-0.537*** **	0.156187	-0.129	0.104479
Constant	0.473	1.578368	-28.03	2593.974	0.765	1.155593	-1.924	2.407852	-22.55	1364.826
No. observation	195		195		195		195		195	
Log likelihood	-71.875		-36.7975		-112.466		-41.490		-31.9095	
LR chi square	36.71		59.65		45.39		66.37		26.34	
Pseudo R^2	0.2034		0.4477		0.1679		0.4444		0.2922	
Prob>chi^2	0.0037		0.0000		0.0002		0.0000		0.0494	

Source: Author's compilation from household survey, 2008
*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

Table 12: Marginal effects of logit model of coping strategies for drought

Variables	Early Planting		Drought resistant		Did nothing		Tree planting		Irrigation Practices	
	Coeff.	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*	*Coeff.*	*Std. Err*
Literacy	**0.167*** **	0.060248	-0.015	0.044432	-0.093	0.086629	0.015	0.053865	0.009	0.041601
Radio ownership	-0.069	0.058558	0.053	0.046685	0.068	0.07197	-0.021	0.043457	-0.032	0.038732
Mobile phone ownership	0.035	0.064105	-0.052	0.045613	0.018	0.087195	0.018	0.056245	0.008	0.039852
Access to electricity	-0.144	0.091262	0.001	0.062651	-0.004	0.106481	0.093	0.061758	0.005	0.061368
FBO	-0.094	0.074043	0.002	0.052501	0.019	0.088958	**0.136** **	0.053907	-0.019	0.056479
Seed source	**0.166** **	0.066775	0.089	0.05594	-0.119	0.073342	**-0.137*** **	0.04193	0.088	0.057785
Age X	0.049	0.08524	**0.151** **	0.078855	-0.170	0.106678	0.020	0.068469	0.742	63.52035
Age Y	0.007	0.080548	0.124	0.076631	-0.134	0.095619	-0.057	0.058069	0.715	63.52034
Gender	-0.078	0.076996	----	---	**-0.193***	0.103318	0.065	0.078993	0.057	0.071909
Household size	-0.017	0.012191	**-0.018** **	0.008601	0.004	0.0139	**0.028*** **	0.007988	0.004	0.006944
Income	**-0.085***	0.051337	**0.129** **	0.062873	0.066	0.06979	-0.042	0.048856	0.001	0.034417
Area BZ	-0.038	0.066003	1.087	156.4405	**-0.250*** **	0.078403	**0.210*** **	0.065125	---	---
Area Z	-0.102	0.092371	0.955	156.4405	-0.150	0.110265	**0.166** **	0.081796	0.077	0.050549
Area TT	-0.019	0.070901	0.973	156.4405	-0.146	0.096848	**0.137***	0.081734	**0.115** **	0.050733
Effect	-0.001	0.056905	**0.073***	0.040757	-0.088	0.072226	-0.036	0.046099	0.049	0.041143
Access to credit	**0.128** **	0.052233	0.014	0.043017	-0.100	0.069941	-0.056	0.047382	0.057	0.038936
Farm size	0.003	0.003931	-0.007	0.006844	**0.022*** **	0.006342	**-0.036*** **	0.008838	-0.006	0.00483
No. observation	195		195		195		195		195	

Source: Author's compilation from household survey, 2008
*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

6.5 Coping Strategy for Bushfires

The results from the study revealed three main effects of bushfire on sampled households are presented in Table 13. Twenty eight survey respondents were affected by bushfires. According to the survey, most farmers (71.4%) affected by bushfire responded that they lost their farm produce as a result of the bushfires that occurred in the 2007/2008 growing season. For others (10.7%) there was no field for their livestock to graze on since a large portion of their grassland were destroyed by the bushfires. Livestock farming in the district and most part of Ghana is primarily ‘free range’ and availability of grassland areas is a significant factor to livestock productivity. Any decline thereof in grazing fields affects farm income and rural livelihood. The other effect of bushfire includes the burning of part or all the buildings of respondents.

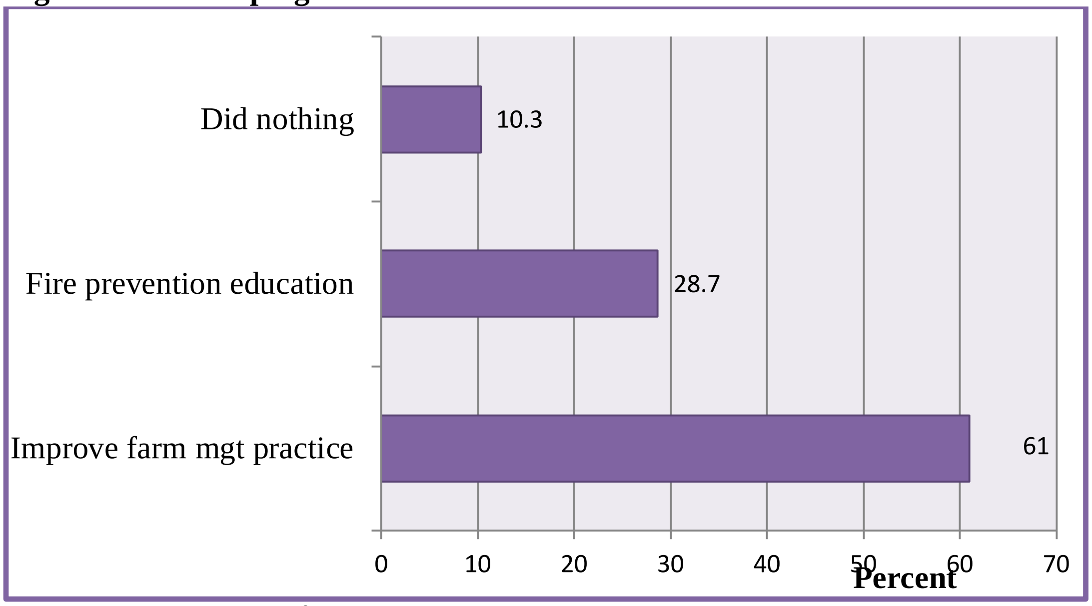
Table 13: Effect of bushfire on households

	Percent
Farm produce burned	71.4
No field for livestock grazing	10.7
Part or all house burned	17.9

Source: Author’s compilation from household survey, 2008
Note: N = 28

In general, most of the 28 sampled households (61%) reported the use of improved farm management practice as a coping measure to bushfires. Such improved management practices included creating fire belts more than two meters from other neighboring farms, regularly clearing weeds around house or farms especially during the dry season and keeping their surroundings clean. Fire prevention educations through anti-bushfire campaigns and household heads educating their wards on the effects and steps to preventing bushfires have been resulted to for adaptation to bushfires. Ten percent did nothing to cope.

Figure 6: Main coping mechanisms for bushfire events



Source: Author's compilation from survey, 2008
Note: N = 195

6.5.1 Factors Influencing the Adoption of Coping Strategies for Bushfires

Results from the BLR for bushfire-induced coping strategies are presented in Tables 14 and 15. The three separate models shown are classified as Model 11 (model with 'improve farm management practices' as dependent variable), Model 12 (model with 'fire prevention education' as dependent variable) and Model 13 (model 'did nothing' as dependent variable). The chi-squared values from the likelihood ratio statistics are highly significant for Models 11 and 12, an indication of a strong explanatory power.

Based on the survey, a limited number of factors were found to influence the adoption of strategies to cope or adapt to bushfire situations. The results of Model 11 show that, seed source, gender, income and effect of bushfires significantly influenced the adoption of improved farm management practices. Similarly, fire prevention education was significantly influenced by radio ownership, source of seeds, gender and income. Also, no adaptation is significantly affected by FBO membership and farm size.

Table 14: Parameter estimates of the logit model of coping strategies for bushfires

Variables	Improve Farm Mgt. Practices		Fire Prevention Education		Did nothing	
	Coeff.	*Std. Error*	*Coeff.*	*Std. Error*	*Coeff.*	*Std. Error*
Literacy	0.558	0.456048	-0.396	0.49438	-0.488	0.75443
Radio ownership	-0.321	0.381835	**0.707***	0.406249	-0.517	0.616791
Mobile phone ownership	-0.254	0.444017	-0.334	0.480136	0.970	0.724005
Access to electricity	0.001	0.569027	0.543	0.560669	-1.496	1.275357
FBO	-0.315	0.459524	0.062	0.477768	-0.368	0.758938
Seed source	**1.562*****	0.372579	**-1.160*****	0.380654	**-1.540*****	0.588036
Age X	-0.208	0.557437	0.202	0.595756	0.125	0.888377
Age Y	-0.455	0.491786	0.193	0.507291	0.282	0.765014
Gender	0.895	0.552359	**-1.082****	0.566768	-0.073	0.852231
Household size	-0.016	0.071451	0.049	0.074265	-0.123	0.119778
Income	**-0.876****	0.379337	**0.777****	0.403234	0.527	0.563901
Area Z	-0.566	0.573391	0.890	0.599049	-0.548	0.944068
Area BZ	0.582	0.433432	-0.141	0.458051	-0.950	0.73333
Area TT	-0.510	0.490513	0.506	0.518245	-0.349	0.729894
Effect	**0.949***	0.573194	-0.789	0.623694	-0.047	0.861477
Access to credit	0.470	0.369762	-0.239	0.384019	-0.568	0.627795
Farm size	-0.009	0.026287	-0.032	0.02971	**0.063***	0.0341
Constant	1.882	1.224403	-2.350	1.298626	-2.242	1.903031
No. observation	195		195		195	
Log likelihood	-110.339		-102.470		-50.912	
LR chi square	40.09		27.06		18.24	
Pseudo R2	0.1537		0.116		0.152	
Prob>chi2	0.0013		0.0572		0.3741	

Source: Author's compilation from survey, 2008
*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

Table 15: Marginal effects of logit model of coping strategies for bushfires

Variables	Improve Farm Mgt. Practices		Fire Prevention Education		Did nothing	
	dy/dx	*Std. Error*	*dy/dx*	*Std. Error*	*dy/dx*	*Std. Error*
Literacy	0.107	0.086341	-0.069	0.085979	-0.036	0.055821
Radio ownership	-0.062	0.072818	**0.123***	0.069238	-0.038	0.04571
Mobile phone ownership	-0.048	0.084991	-0.058	0.083566	0.071	0.053637
Access to electricity	0.0003	0.109183	0.095	0.097257	-0.110	0.094536
FBO	-0.060	0.087807	0.010	0.083501	-0.027	0.056137
Seed source	**0.299*****	0.058904	**-0.202*****	0.060997	**-0.113*****	0.043917
Age X	-0.039	0.106844	0.035	0.104042	0.009	0.065711
Age Y	-0.087	0.09371	0.033	0.088584	0.020	0.056521
Gender	**0.171***	0.103526	**-0.189****	0.095974	-0.005	0.063031
Household size	-0.003	0.013702	0.008	0.012931	-0.009	0.008873
Income	**-0.168****	0.069398	**0.135****	0.068471	0.039	0.041626
Area Z	-0.108	0.109037	0.155	0.102744	-0.040	0.069821
Area BZ	0.111	0.081824	-0.024	0.079998	-0.070	0.054532
Area TT	-0.09	0.093179	0.088	0.089823	-0.025	0.053978
Effect	**0.182***	0.107491	-0.138	0.107651	-0.003	0.063719
Access to credit	0.090	0.069966	-0.041	0.066908	-0.042	0.046462
Farm size	-0.001	0.005039	-0.005	0.00514	**0.004***	0.002513
No. observation	195		195		195	

Source: Author's compilation from household survey, 2008
*Note: *, ** and *** represent significance at 10%, 5% and 1% respectively*

According to the regression results, radio ownership is positively and significantly related to the adoption of fire prevention education as an adaptive measure to bushfires. Households with access to radio are privilege to lots of information on bushfire control and prevention. This suggests that, anti-bushfire campaigns on radio and other media channels is an effective way of reducing occurrence of bushfires. Ownership of a radio increased the probability of using fire prevention education to cope with bush fires by 0.124.

Source of seeds appeared to be negatively associated with improve farm management practices and no adaptation. The negative sign on seed source in models 11 and 13 suggests a smaller likelihood for farmers that depend on their own stored seeds as the main source of seed for planting to cope with bushfires by improving doing nothing or embark on fire prevention education respectively. Contrarily, the probability of adopting improved farm management practices is 0.299 greater for farmers who use their own seeds for planting than those who depends on government for their seed provision.

Low-income households tend to improve their farm management practices while high income households resort to fire prevention education to cope with bushfires. Also, male household heads have a higher tendency to adopt improve farm management practices and fire prevention education as strategies to adapt to bushfires. There exit positive significant correlations between gender and improve farm management techniques and fire prevention education. Again males are well educated, and have relatively easy access to information and resources, explaining this outcome.

The prior expectation was for the effect of bushfires on households to significantly affect adaptation. However, only improve farm management practices appeared to be significantly influenced by effect of bushfires on households. This finding suggests that households that have experienced a negative effect from bushfires are likely to adapt by improving their farm management practices (creating fire belts around farm or house and regularly weeding around farm or house). This likelihood is 0.182 higher for households that have suffered from bush fires than those otherwise.

The next chapter will summarize the major findings of the study and provide potential policy initiates that are vital to enhancing households' adaptive capacity.

Chapter 7 – Conclusions and Policy Recommendations

Climate is changing faster in Northern Ghana relative to other parts of the country. Prolonged high temperatures and fires that burn crops coupled with erratic rainfalls have characterized the climatic pattern of the region over the period 1983 to 2011. As the poorest and most agricultural dependent region of Ghana, the impact of such climatic conditions is devastating. A clear example is the 2007/2008 prolonged drought season which was followed immediately by a devastating flood in the entire Northern Ghana. Several food crops and livestock were destroyed (some washed away by the flood) causing severe food shortage; farm income declined; buildings, roads and other infrastructure collapsed; yield from crops declined and countless people were rendered homeless.

This study examined the effect of extreme climatic conditions (drought, flood, and bushfires) on the livelihood of households in the Bawku West district of Ghana, identified the mechanisms with which these households cope in such situations, and analyzed factors influencing the adoption of coping strategies for flood, coping strategies for drought and coping strategies for bushfire respectively. Data for the study were collected in selected villages across the district in the aftermath of the 2007/2008 extreme events. A binary logit regression model was used to estimate factors that influence the adoption of given coping mechanisms. In all 13 coping mechanisms were identified to be used by households in the event of flood, drought or bushfires.

Evidence from the study showed the destruction of crops as the major effect of flood on households. Other effects included food shortage and the destruction of livestock and household buildings. Expectations would have been for households to develop effective strategies to cope, but surprisingly an overwhelming proportion of households reported no adaptation (or did nothing) as a coping measure to flood. NGO or government supports, modern building techniques, early planting, improve drainage system and farming in lowland areas were identified as the other main coping strategies to flood. Several factors significantly influenced the adoption of these flood-induced coping measures. Among them are the size of household, farm size, access to credit, household income, access to electricity, membership with an FBO, source of seed for planting, farm size, location of household and the impact of drought on households.

On the other hand, the impacts of drought on affected households were poor yield or harvest, destruction of crops and livestock and water shortage. The main coping mechanisms households resorted to in the event of drought comprised irrigation or dry season farming, food storage, trees or cover crop planting, planting drought tolerant or early yielding crops and early planting. From the results of the BLR for coping strategies for drought, it was concluded that the literacy level of household head, size of household, farm size, access to credit, household income, source of seed for planting, membership with an FBO, gender, location of households, household head aged between 40-39 years and the impact of drought on households affected the probability of households adapting to drought conditions.

According to the study results, a limited number of factors significantly influenced the adoption of coping strategies for bushfire. They included radio ownership, membership with an FBO, gender, location of households, source of seed for planting, household income and the impact of drought on households. Surveyed respondents reported fire prevention education and improve farm management practices as the main tools used for adapting to bushfires.

Though the focus of this paper is on climate change, it is worth noting that the incidence of flood in most developing regions cannot be attributed entirely on changes in the ecosystem. Another contributory factor as shown implicitly from the result of the study is a matter of proper land, housing and infrastructure management (such as rivers overflowing their banks, choked gutters etc.).The quest for a improved drainage system as indicated by 14 percent of sampled households could explain this phenomenon. Management of the ecosystems to achieve reasonable outcome requires a concurrent management of local infrastructures.

Drawing on the results of the study, the need for appropriate government policies in mitigating the harsh effects of extreme climatic events on the well-being of households in the Bawku West district is critical. Government policies could strengthen the current adult education program to encourage and increase literacy level among older individuals. Households better adapt to climate change if they utilized their own seeds for planting. Therefore, policies directed towards readily accessible and affordable improved seeds to households could be beneficial to adaptation. Moreover, government policies could facilitate easy access to extension, and farm credit. Farmers could be educated on the use of proper farm management techniques as it increases the likelihood of adaptation. The recent breadbasket initiative in selected villages in Ghana by the Alliance for Green Revolution is typical of an income-generating source for farming households. Under this initiative, farmers gain access to extension service, and access to credit to purchase farm inputs like fertilizer and quality seeds. Such initiatives in the district would encourage income generation and minimize severe food shortage. Policy intervention that simplifies and expedites information dissemination (on anticipated change in climate and necessary coping measures) through radio and other public media will enhance households' adaptive capacity.

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