UNIVERSITY OF CAPE COAST

FARMERS' VULNERABILITY AND ADAPTATION TO DROUGHT IN THREE AGRO-ECOLOGICAL LOCATIONS IN GHANA

HILLARY DUMBA

2019

UNIVERSITY OF CAPE COAST

FARMERS' VULNERABILITY AND ADAPTATION TO DROUGHT IN THREE AGRO-ECOLOGICAL LOCATIONS IN GHANA

By

HILLARY DUMBA

Thesis submitted to the Department of Geography and Regional Planning of the Faculty of Social Sciences, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of Doctor of Philosophy degree in Geography

MAY 2019

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature ………………………… Date ………………………

Name: Hillary Dumba

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature……………… Date ………………………

Name: Dr. Benjamin Kofi Nyarko

Co-supervisor's Signature……………………Date ………………………

Name: Dr. Abrefa Danquah Jones

ABSTRACT

The study adopted a pragmatist approach to assess farmers' vulnerability and adaptation to drought in three agro-ecological-locations in Ghana. It analysed the variations in precipitation deficits by using precipitation values for 1983-2014 period. It also assessed the variation in drought vulnerability, farmers' adaptation and barriers to drought adaptation. The cross-sectional survey design was utilised. A random sample of 326 farmers and six purposively selected lead farmers participated in the study. Questionnaire and interview schedules were used to collect data. The data were analysed by using SPI, descriptive and inferential statistics. The study revealed that Wa West District has the highest drought vulnerability index followed by Nkoranza North and Wassa East Districts. The study also found a significant variation between locations and drought vulnerability and adaptation. The most common drought adaptation measures comprise application of agro-chemicals, changing planting date, cultivating different crop, integrating crop and livestock production, changing the location of crops, diversifying from farm to non-farm income generating activities, cultivation of early maturing crops and drought monitoring. Shortage of water for irrigation, unavailability of financial resources, high cost of agricultural inputs, inadequate knowledge and insufficient access to extension services served as barriers that constrained farmers' drought adaptation. Therefore, it was recommended, among other things, that philanthropic organisations should assist the government to construct small-scale irrigation facilities and provide drought-resistant crops to farming communities in Ghana.

KEY WORDS

Adaptation

Agro-ecological location

Climate change

Drought

Farmers

Vulnerability

ACKNOWLEDGEMENTS

The completion of this work would have been dreadful without the generous assistance, contributions and encouragement from some individuals. I am particularly thankful to Dr. Benjamin Kofi Nyarko and Dr. Abrefa Danquah Jones, two scholars who served as my Principal Supervisor and Co-supervisor respectively. Your great comments, critiques and suggestions made me rethink and reshape the work.

The following family members also deserve special thanks and appreciation: my beloved father, Marcel Dumba, my mother, Lucy Dumba, my brothers namely Stephen Boye, Dr. Braimah Balika, Augustine Ang-leoha, Gaeten Boye, Francis Dumba, Lambert Dumba, Michael Dumba, Fidelis Dumba, Rogation Dumba, James Dumba and Vitus Dumba. Thanks for the unfailing prayers, moral support and financial assistance throughout my educational career. May you continue to receive His divine mercy.

My heartfelt appreciation also goes to Dr. A. L. Dare, Prof. A. L. Dei, Prof. Kwabena Barima Antwi, Prof. Kankam Boadu, Alhaji Dr. M. B. Yidana, Dr. Bukari Shaibu, Dr. Hipolyte Angbing, Dr. B. T. Ababio, Prof. Augustine Tanle, Prof. Simon Mariwah, Prof. Kofi Tsivanyo and Dr. Charles Oppong Adabo for your previous academic advice, encouragement and diverse support services.

Finally, I am also thankful to the entire Banaaleh family, Bernard Fentim Darkwah, Stephen Naah, Kweku Anhwere, Kweku Holman, Rev. Dr. Martin Owusu, Dr. Francis Taale, Osman Adams, Peter Anti Partey, Alim Musah, Andews, Addai and Samuel Bentil.

DEDICATION

To my wife, Rainer Banaaleh and children, Aurelia, Hester, Hillary Jnr and Keren.

TABLE OF CONTENT

Content **Page**

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF ABREVIATIONS

AMCEN	African Ministerial Conference on Environment
ATPS	African Technology Policy Studies
BBC	British Broadcasting Corporation
DFID	Department for International Development
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organisation
GMeT	Ghana Meteorological Agency
GSS	Ghana Statistical Service
GWP	Global Water Partnership
IPCC	Inter-governmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
NASA	National Aeronautics and Space Administration
NND	Nkoranza North District
NNDA	Nkoranza North District Assembly
SAA	Sub-Sahara Africa
SPI	Standardized Precipitation Index
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WED	Wassa East District
WEDA	Wassa East District Assembly
WICCI	Wisconsin Initiative on Climate Change Impacts
WMO	World Meteorological Organisation
WWD	Wa West District
WWDA	Wa West District Assembly

CHAPTER ONE

INTRODUCTION

Farmers in Africa are not helpless in moments of climate change; they adapt to climate change and variability in several ways (Golo & Yaro, 2013), but the speed and magnitude of the projected climate change in most parts of SSA is likely to outpace local farmers' adaptive capacity (Burke & Lobell, 2010). Climate change and drought adaptation mechanisms are not clearly defined and farmers' level of climate literacy in Ghana is still minimal (Amponsem, 2015). This suggests that farmers in Ghana are susceptible to unfavourable climate patterns such as drought. This study sought to expand our knowledge and understanding of farmers' vulnerability and adaptation to drought in selected agro-ecological locations in Ghana. Chapter One is focused on general introduction to the study. It presents the background to the study, the statement of the problem, purpose of the study, research questions and hypotheses, significance of the study, delimitation, and organisation of the study.

Background to the study

Agricultural production constitutes the largest economic activity in Africa and about 95 per cent of its cropland depends on rainfall (Inter-Governmental Panel on Climate Change [IPCC], 2007; Laux, 2010). Rainfall variability is expected to severely undermine agricultural productivity and households' access to food in most parts of Africa. Drought is the greatest climatic threat and disturbance to agriculture as well as food and nutritional security in Africa (Shiferaw, Tesfaye, Kassie & Abate, 2014; United Nations Framework Convention on Climate Change [UNFCCC], 2007). Agriculture is very sensitive to climatic variability (Shiferaw et al., 2014) and climatic patterns to a large extent determine the success or failure of crop and livestock production. Climate-related shocks and extremes would aggravate the vulnerability of agricultural systems, amplify biodiversity loss, and also deepen water scarcity and climate-related health crises in Sub-Sahara Africa (IPCC, 2014). Climate change affects human economic activities and survival regardless of location. Human activities such as agriculture are vulnerable to climate change. Agriculture, which serves as the main source of food supply and national revenue, is more vulnerable to the impact of climate change compared to other sectors (Arfanuzzaman, Mamnun, Islam, Dilshad & Syed, 2016; Cervantes-Godoy & Dewbre, 2010; Luwesi, Obando & Shisanya, 2017). Changes in elements of climate and weather determine crop and livestock production and farmers' vulnerability as well as adaptation response in various spatial settings.

Among all climate change-induced disasters, drought is the costliest and most devastating climatic disaster that imposes untold adverse consequences on human activities. Its recurrent occurrence is associated with high level of vulnerability among farming households (Makoka, 2008; United Nations, 2010; Wilhite, 2000). It severely affects agriculture in rural areas as well as trade and food security in both developed and developing economies of the world. Drought is particularly hazardous to communities which depend on agriculture for livelihood (Chhinh, 2015; Diaz, Hurlbert & Warren, 2016; Swain & Swain, 2011).

Drought vulnerability is a global phenomenon and it occurs in every agro-ecological location. All continents in the world are vulnerable to drought.

For instance, Forster et al. (2012) projected that drought will seriously hamper wheat and maize production in China and India which are Asia's largest producers of food in the next two decades. This situation would threaten food security in Asia. Farmers' in Sertão in South America are also vulnerable to drought as a result of crop and animal loss (Burney et. al., 2014). Similarly, in the United States of America, drought has imposed USD $2.2 billion cost and 3.8 percent cut in employment rate in California (Carlton, 2014) and a decline in the availability of irrigation water which in turn lessened quantity, quality and marketability of agricultural produce in Washington (Washington State Department of Agriculture, 2015). In 2011, drought in Texas caused a $7.62 billion loss in the agricultural sector only (Ziolkowska, 2016).

Agricultural production in tropical and sub-tropical climates is most likely to be severely affected by climate change while regions in temperate and polar climates will benefit from it (Devereux & Edwards, cited in Yaro, 2013). Although all continents are vulnerable to impacts of drought, African countries are more vulnerable to drought compared to other regions of the world. This is because the agricultural sector of most countries in the African continent depends on rainfall. Rainfall is the most critical hydrological variable that determines agricultural production in Africa. Africa has less than 5 per cent irrigated agriculture. Except Egypt, Sudan, Madagascar, Morocco and Sudan, only 4 percent of the area cultivated in SSA is under irrigation (Svendsen, Ewing, & Msangi, 2009; You, 2010). Deficit in normal rainfall creates drought conditions which pose the greatest threat to agriculture as well as food and nutritional security in Sub-Saharan Africa. In 2011, drought hit the Horn of Africa and resulted in food and water insecurity as well as mortality of livestock and tens of thousands of people (Africa Ministerial Conference on Environment [AMCEN], 2011; British Broadcasting Corporation [BBC], 2012).

Although Ogalleh, Vogl, Eitzinger and Hauser (2012) argue that drought has increased the vulnerability of most smallholder farmers in SAA, it is still projected that drought will severely undermine agricultural productivity and households' access to food in most parts of the African continent leading to welfare losses and suffering among smallholder farmers (African Technology Policy Studies [ATPS], 2013). Climate-induced drought would also drastically reduce the quantity and quality of suitable arable lands, the lengths of the cropping seasons and the level of crop productivity and yields (Bang & Sitango, 2003; IPCC, 2007; ATPS, 2013; Yaro, 2013). Moreover, food production from rain-fed agriculture will reduce by 50% in the 2020s due to drought. This will consequently intensify the level of poverty and malnutrition along arid and semi-arid margins of the African continent (IPCC, 2007; 2014; Shiferaw et al., 2014).

Incidence of drought is prevalent in Ghana, with the 1983 being the severest and most destructive in the history of the country. Drought conditions impose consequences on crop yield and food security (Laube, Awo & Schraven, 2008; Van der Geest, 2004; Van de Giesen, Liebe & Jung, 2010; Yaro, 2004). Previous report indicated that persistent drought conditions affected all investments in the agricultural sector in the country. Unreliable rainfall, prolonged droughts, coupled with high temperatures have severely affected sustainable agriculture in the country (Armah et al, 2011; Dietz, van der Geest & Obeng, 2013; Ghana Statistical Service [GSS], 2013). Drought conditions exhibit spatio-temporal characteristics. Thus, it varies across geographic locations and time throughout Ghana. According to Amponsem (2015), agricultural stakeholders have acknowledged that variations in rainfall patterns over the past years have hurt farming activities in various parts of the country.

Evidence suggests that the vulnerability of agricultural production to drought in Ghana has apparent geo-spatial and socio-economic patterns. Yaro (2013) argues that there is spatial vulnerability to climate change in Ghana. Thus, there are various degrees of vulnerability to climate change and drought depending on the agro-ecological zone where farmers are located. The savannah agro-ecological zone is generally considered as the most vulnerable place to drought. The other ecological zones exhibit varying degrees of climate change vulnerability with Ashanti and Greater Accra regions which are the most developed and urbanized regions being the lowest vulnerable regions in the country (Antwi-Agyei, Fraser, Dougill, Stringer & Simelton, 2012; Osei-Owusu, Al-Hassan & Doku-Marfo, 2012). The Savannah and Sudan agro-ecological zones experience more extreme drought and dry spell conditions which eventually affect agriculture, the environment, and human livelihoods and increase the overall vulnerability status of these ecological zones relative to the other agro-ecological zones in the country (Stanturf et al., 2011). However, the forest zone has more favourable climatic conditions compared to the other agro-ecological zones of Ghana. This zone, therefore, serves as the hub that receives vulnerable migrants from northern Ghana.

The geo-spatial variation in farmers' vulnerability to drought in Ghana is well-supported by the theory of community disaster vulnerability. This theory as proposed by Zakour and Gillespie (2013) espouses that vulnerability to disaster is not evenly distributed across regions but varies across geographic contexts. Vulnerability to disaster differs from individual person to person and place to place (World Bank, 2010; Zakour & Gillespie, 2013; Zarafshani et al., 2016). According to this theory, individuals and regions are vulnerable to disasters due to lack of adaptive capacity within the local physical environment to mitigate the adverse consequences of hazards (Oliver-Smith, 2004; Zakour & Gillespie, 2013). The susceptibility of individuals, groups, organisations, communities, and countries to harm from exposure to disasters and external stresses are associated with social and environmental changes in the absence of adaptive capacities and resilience (Adger, 2006; Zikour & Gillespie, 2013).

Within the context of climate change, vulnerability is an umbrella term for the presence of sensitivity or susceptibility to being harmed due to lack of capacity to cope with or adapt to the harm, including the adverse effects of climate variability and unfavourable weather patterns (Brant, 2007; Harley, Horrocks, Hodgson & van Minnen, 2008; World Bank, 2010; Zakour, 2010; IPCC, 2014). In research, farmers' exposure and sensitivity to drought in the absence of adaptive capacity are the common metrics for assessing their vulnerability to drought (Aulong & Kast, 2011; IPCC, 2007; 2014). These major drivers of farmers' vulnerability differ from one geographical location to another and thus, their drought vulnerability is unlikely to be same (Aulong & Kast, 2011; Brooks, Adger & Kelly, 2005; Johnson & Brell, 2012; Smit & Wandel, 2006; Zarafshani, Sharafi, Azadi, & van Passel, 2016). This is because when drought occurs within a single defined territorial area, farmers in that area possess different economic, socio-cultural, psychological, technical and infrastructural factors that determine their adaptive capacity to fight and mitigate the concomitant adverse effects of drought in different ways.

Ajzen's (1985) theory of planned behaviour argues that individuals perform certain planned actions known as behaviours in response to the achievement of a target. In a similar fashion, given the serious problems posed by drought to agriculture in Ghana, farmers practice adaptation to overcome or reduce the resultant vulnerability. In the literature of climate change, adaptation is defined by IPCC (2014) as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or takes advantage of the benefits. The variations in drought patterns and farmers' vulnerability to drought across the agro-ecological locations of Ghana make farmers adopt certain adaptation mechanisms that are time, location- and context-specific (Bawakyillenuo, Yaro & Teye, 2016; Jawura, 2014; Yaro & Hesselberg, 2016). Location- and context-specific planned adaptation strategies are essential, effective and sustainable. This is because the local context determines the specific adaptation approaches and initiatives that are most effective and suitable to meet the collective needs of the local people (Bawakyillenuo et al., 2016; Luni, Maharjan & Joshi, 2012; Simpson, Gössling, Scott, Hall & Gladin, 2008). Ajzen's (1985) further theorized that individuals planned actions are influenced by attitude towards the behaviour, subjective norms and behavioural controls. Similarly, adaptation to climate change is influenced by socio-economic, institutional, demographic, cultural and geographical factors

(Amare & Simane, 2018; Fosu-Mensah, Vlek & MacCarthy, 2012; Schilling & Remling, 2011). It is a joint derivative of wealth, technical know-how, information, knowledge, skills, infrastructure, and existence of institutions. These factors determine a person's capacity to deal with risks. The adaptive capacities of various communities can be undermined by lack of formal education, diminished resource bases, income inequalities, weak socio-political institutions and inadequate technology (Abdul-Razak & Kruse, 2017; UNFCC, 2007; 2011). Thus, farmers who are located in a particular agro-ecological zone and well-endowed with resources would possess strong adaptive capacity and therefore less vulnerable to drought compared with other less resource endowed farmers located in different agro-ecological context.

Statement of the problem

Knowledge and information on rainfall distribution in Ghana is largely available. Rainfall deficit results in drought which varies across agro-ecological locations in Ghana. According to Amponsem (2015), agricultural stakeholders have acknowledged that variations in rainfall patterns over previous years have hurt farming activities in the country. However, much attention has not been devoted to describe the spatio-temporal variation of drought, its impact as well as farmers' adaptation to drought in various agro-ecological zones in Ghana. Though farmers are vulnerable to the adverse impacts of drought, appropriate measures to fight drought are not clearly defined among agrarian communities in Ghana (Amponsem, 2015). This suggests that most rural farmers may find it challenging to adapt to drought and hence, susceptible to its impacts.

Evidence indicates that rain-fed agriculture constitutes the main livelihood activity in the selected agro-ecological locations. For instance, crop farming (96.1%) is the major activity undertaken by households in the Wassa East District while most households (97.2%) in the Wa West District are engaged in crop farming as the main economic activity. Similarly, almost all agricultural households (98.5%) in the Nkoranza North District are involved in crop farming (GSS, 2014). However, rainfall pattern has not only changed, but has become erratic and the amount received has also drastically reduced. Droughts, coupled with limited and erratic rainfall affect agricultural productivity, particularly farmers' crop yield (Antwi et al., 2015; GSS, 2014).

Numerous studies have examined farmers' vulnerability and adaptation to climate change in different locations and contexts (Apata, 2011; Fosu-Mensah et al., 2012; Mabe et al., 2014; Obayelu et al., 2014; Ringer et al., 2014; Songwe, Masuku & Manyatsi, 2014). However, these studies are not only predominantly quantitative but also based broadly on farmers' vulnerability and adaptation to climate change. The findings are highly aggregated and hence, do not address rural farmers' vulnerability and adaptation to drought in the Ghanaian context. Farmers' vulnerability and adaptation to climate change is dependent upon specific climate change events and hence, may differ from one climatic event to another. The measures being employed to adapt to other climate change events may differ from strategies employed to adapt to drought. Therefore, a clear understanding of farmers' vulnerability and adaptation to drought is desirable for designing and implementing appropriate drought adaptation strategies to enhance sustainable agriculture in Ghana.

Most empirical studies on drought spatio-temporal variation, farmers' vulnerability and adaptation to drought are not conducted in the Ghanaian context. Therefore, empirical evidence on drought spatio-temporal variation, farmers' vulnerability and adaptation to drought is unavailable and this does not augur well for micro-level drought adaptation planning and management in the country. Based on this scenario, this mixed-method study was designed to examine farmers' vulnerability and adaptation to drought in the Wassa East, Nkoranza North and Wa West Districts of Ghana.

Purpose of the study

This study primarily sought to assess crop farmers' vulnerability and adaptation to drought in three agro-ecological locations in Ghana. Specifically, the study sought to:

i. analyse the spatio-temporal variation in drought in the selected agro-ecological locations for the period of 1983-2014.
ii. determine whether there is any significant variation in farmers' vulnerability to drought among the selected agro-ecological locations.
iii. examine farmers' adaptation to drought in the selected agro-ecological locations.
iv. assess the factors that constrain farmers' adaptation to drought in the selected agro-ecological locations.

Research questions

The study was guided by the following research questions:

1. What is the spatio-temporal variation in drought for the period of 1983-2014 in the agro-ecological locations?
2. What are farmers' adaptations to drought in the selected agro-ecological locations?
3. What factors constrain farmers' adaptation to drought in the selected agro-ecological locations?

Research hypotheses

The following hypotheses were empirically tested:

$H_{0:}$ There is no statistically significant variation in drought vulnerability across the selected agro-ecological locations.

$H_{A:}$ There is statistically significant variation in drought vulnerability across the selected agro-ecological locations.

$H_{0:}$ There is no statistically significant difference in farmers' adaptation to drought across the selected agro-ecological locations.

$H_{A:}$ There is statistically significant difference in farmers' adaptation to drought across the selected agro-ecological locations.

Significance of the study

This study will offer practical and theoretical contributions in the following ways. In the first place, it is envisaged that the study will provide information on drought exposure and its spatio-temporal dynamics in the selected areas. These results will help improve our knowledge and understanding of precipitation and drought pattern in the selected agro-ecological locations.

Secondly, the study will also highlight the barriers that confront farmers' adaptation to drought. This will provide the necessary information to assist the government and the civil society to develop and strengthen appropriate adaptation strategies that can best serve the specific needs and challenges of farmers in the selected agro-ecological locations in particular and Ghana at large. Thus, information from this assessment will help in developing and improving drought adaptation strategies and policies in the country which will in turn enhance farmers' adaptive capacities in dealing with the devastating effects of drought.

Finally, the study will also expand our theoretical knowledge and understanding of drought vulnerability assessment and adaptation planning. The results of this study will build on the theory of planned behaviour as proposed by Ajzen (1985). Specifically, the study will shed more light on farmers' planned behaviour towards drought and their perceived behavioural controls that act as barriers to planned adaptation to drought. This will pprovide the necessary information and reference material for other researchers and drought management policy-makers.

Delimitation

The twin factors of time and resource constraints made it impossible to examine all the variables of interest on a large-scale. Therefore, the study is delimited in terms of methodological techniques and variables of interest.

In the first place, only precipitation data from 1983-2014 was used to calculate the drought index. This is because using SPI for drought analysis requires only precipitation data which is at least 25 years old. Besides, rainfall data constitutes the single most important hydrological variable that determines agricultural productivity (Tilahun, 2006) more especially in Ghana. Similarly, Sivakumar, Das and Brunini (cited in Atwi-Agyei, 2012) indicated that decline in crop productivity is always attributed to unusually precipitation-induced drought rather than warming-induced increases in evapotranspiration rates.

The study assessed the extent to which farmers are vulnerable to drought based on perceived drought sensitivity, exposure and farmers' adaptive capacity in the selected agro-ecological locations. The adoption of drought adaptation mechanisms as well as the factors that constrain farmers' use of drought adaptation mechanisms was also examined.

The study also explored only farmers' views on the use of both on-farms and off-farm measures to combat drought. It excluded the role of external bodies such as government and agriculture extension officers in assisting farmers to adapt to drought.

In terms of spatial coverage, a study of this calibre should have assumed a nation-wide dimension. However, it was conducted in three agro-ecological locations namely Wa West, Nkoranza North and Wassa East Districts of Ghana.

Organisation of the study

The research is organised into nine chapters. The first chapter provides the background and rationale to the research. It presents the statement of the research problem, general aim, specific objectives as well as the research questions and hypotheses. It also contains the significance of the research and delimitation. It finally outlines the structure of the study.

The second chapter focuses on a review of theoretical, conceptual and empirical literature that is relevant to the issue under investigation. The review consists of the concept of vulnerability and vulnerability assessment approaches. Bohle's Framework, the Sustainable Livelihood Framework, Theory of Disaster Vulnerability and the Theory of Planned Behaviour have also been discussed to provide the theoretical explanation and perspective for this current research. The chapter also discusses the concept of drought and its types. It finally contains empirical discussions on drought impacts and vulnerability, drought adaptation and management as well as the spatio-temporal variation in rainfall in Ghana.

Chapter Three presents a discussion of the general approaches and techniques that were employed to carry out the study. The Chapter describes the study areas, research paradigm and design, population, sample and sampling procedure, research instruments, reliability and validity of the research instruments, data collection procedure and ethical considerations. The data processing and analysis procedures as well as and limitations of the study are also outlined in this chapter.

Chapter Four discusses the socio-demographic characteristics of the respondents. These socio-demographic characteristics comprise participants' gender, age, marital status, level of formal education, farming experience, farm size, household size, size of landholding as well as number of dependents.

The results and discussion on spatio-temporal variability of drought are presented in Chapter Five. The discussion is based on SPI for drought in each study area.

In Chapter Six, farmers' vulnerability to drought in the various agro-ecological locations are presented. The discussion also focuses on the socio-economic and environmental impacts of drought. The Chapter finally presents spatial variation in farmers' drought vulnerability across the selected agro-ecological locations.

Chapter Seven is devoted to results on farmers' adaptation to drought. It highlights the adaptation mechanisms that farmers employ to adapt to drought. The Chapter also discusses the influence of agro-ecological location and farmers' socio-demographic factors on their choice of specific drought adaptation strategies.

The results on factors that constrain farmers' adaptation to drought are presented and discussed in Chapter Eight. The discussion focuses on factors that act as barriers to prevent farmers from implementing drought adaptation strategies.

Finally, Chapter Nine focuses on the summary, conclusions and recommendations of the study. Based on the findings and conclusions, appropriate recommendations are made to other bodies and agencies. Suggested areas for further research are also captured in this chapter.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter presents a review of literature relevant to the issues being investigated. The Chapter deals with both theoretical and empirical review. It discusses various theoretical and conceptual perspectives have been espoused to explain the vulnerability of individuals and societies to natural hazards as well as beliefs and intention on responding to the adverse effects that emanate from these natural hazards.

This present study is premised on various theoretical and conceptual considerations. Theory of Disaster Vulnerability proposed by Zakour and Gillespie (2013), Ajzen's (1985) Theory of Planned Behaviour, Bohle's (2001) Conceptual Framework, the Sustainable Livelihood Framework (DFID, 1999) and the Integrated Vulnerability Assessment approach (Deressa et al., 2008; IPCC, 2001; 2014) have also been discussed in this Chapter. These theories and approaches were utilized to provide theoretical explanations and justification for farmers' vulnerability and adaptation to drought. The discussion of related literature helps to develop a conceptual framework to guide this current research. The Chapter also contains a review on empirical studies on farmers' vulnerability and adaptation to drought as well as barriers to farmers' adaptation to climate change.

Concept of vulnerability

Vulnerability is an elusive concept that defies a single universally accepted definition and assessment (Moret, 2014; Zarafshani et al., 2016). Vulnerability connotes the state of exposure or the possibility for a system or a person to be attacked or harmed. The harm or attack can be either physical or emotional. Vulnerability also describes the level of exposure and sensitivity to perturbations or external stresses, and the capacity of a system to adapt to externally imposed stresses. After the process of adaptation, the level of vulnerability is a measure of the remaining adverse consequences from a hazard (Adger, 2006; Kelly & Adger, 2000; Soanes & Stevenson, 2005).

The term vulnerability, according to O'Brien, Eriksen, Schjolden and Nygaard (2004; 2007), can be assessed as a starting point or an end point approach. Starting-point approach views vulnerability as the general characteristics of a system generated by several socio-environmental factors and processes and worsened by climate change (Kelly & Adger, 2000). In this approach, vulnerability determines people's adaptation and adaptive capacity. End-point approach views vulnerability as a factor which is determined by adaptations and adaptive capacity. Hence, vulnerability in the end-point approach is the residual impact of climate change minus adaptive capacity. Each interpretation has implication on how vulnerability research is carried out (O'Brien et al., 2004; 2007). This present study is based on the end-point approach conceptualization of vulnerability.

Vulnerability is a nebulous, multi-dimensional concept. It has magnitude (Calvo & Dercon, 2005) and it is both context and scale-dependent (Harley et al., 2008; Wolf, Lincke, Hinkel, Ionescu & Bisaro, 2008; Aulong & Kast, 2011). Communities and households have differential scales of vulnerability. This explains the reason behind the use of terms like more vulnerable to mean those who are more at risk when referring to vulnerable people, while those that are extremely vulnerable mean those who are 'worse off' and can be placed on the extreme end of the spectrum of vulnerability scale (Wisner, Blaikie, Cannon & Davis, 2003). According to Buckle, Mars and Smale (2000), vulnerability has differential degrees and is usually expressed on a scale from 0 (implying no damage) to 1 (to imply total damage). In the context of framers' vulnerability assessment, score that is closest to one denotes more vulnerable farmer while score that is closest to zero means the less vulnerable (Aulong & Kast, 2011).

Components of vulnerability

Broadly speaking, a society's vulnerability to natural or human-induced climate variability and change is not only a manifestation of its degree of exposure and sensitivity, but its capacity to adapt. The concept of vulnerability encompasses three key components namely, exposure, sensitivity, and adaptive capacity of a system (Kelly & Adger, 2000; McCarthy, Canziani, Leary, Dokken & White, 2001; Burton, Diringer & Smith, 2006; IPCC, 2007; 2014). These components are structurally expressed as follows:

Vulnerability = [susceptibility (S) + exposure to harm (E)] - adaptive capacity (AC). Mathematically therefore, $V = [S+E–(AC)]$. This equation implies that the vulnerability of a system refers to the degree of harm and susceptibility to perturbations in the absence of adaptive capacity. It refers to the residual impact of adaptation (Smit & Wandel, 2006). These components are intertwined and function in synergy to determine the level of vulnerability of a social group or system to a disaster. Thus, Adger (2006) concludes that vulnerability is a "function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (p. 275).

Exposure: Exposure refers to the likelihood of an extreme event occurring and influencing a defined area (Abraham, 2006). Exposure is the "degree, duration, and/or extent in which the system is in contact with, or subject to, the perturbation" (Gallopín, 2006, p. 296). Exposure occurs when people and their livelihoods, environmental functions, species or ecosystems, resources and other services, infrastructure, socio-economic, and cultural assets come into contact with places and settings that could adversely affect them (Adger, 2006; Burton et al., 2006; IPCC, 2014). In this study, drought exposure is conceptualized as the severity and frequency of drought as perceived by farmers.

Sensitivity: This refers to the biophysical component of vulnerability. This measures the level of damage caused by climate change on social and biological systems. This is the "degree to which the system is modified or affected by a disturbance or set of disturbances" (Gallopín, 2006, p. 295). Sensitivity relates to the potentiality for a system to be either adversely or beneficially affected by climate-related stimuli like floods, global warning and droughts (Harley et al., 2008; IPCC, 2014). In drought vulnerability assessment, sensitivity represents the socio-economic and environmental impact of drought on social and bio-physical systems. The potential impact of drought is usually captured by exposure and sensitivity indicators which are two inseparable components of vulnerability (Smit & Wandel, 2006).

Adaptive capacity: Adaptive capacities are the characteristics of communities, people and systems which can be used to counter and cope with environmental disasters (Adger, 2006; Moench & Dixit, 2007). It is a measure of the ability of a system to adjust to the impact of climate change and variability and other perturbations; moderate likely damages; utilize available opportunities and advantages to cope with the consequences of an event (McCarthy, et al., 2001; Gallopín, 2006; IPCC, 2007; Harley et al., 2008; Norris, Stevens, Pfefferbaum, Wyche & Pfefferbaum, 2008). This suggests that there exists an inverse functional relationship between the adaptive capacity and vulnerability of a system. According to Agyei-Antwi et al. (2012, p. 327), adaptive capacity refers to the "ability of a region to cope with the impacts of climate change (particularly drought)". A community that possesses a strong adaptive capacity is less vulnerable to the outcome of hazardous events and vice versa (World Bank, 2010). Farmers' access to various resources was used as proxy for farmers' adaptive capacity to adapt to drought.

Vulnerability and resilience

Vulnerability has a reciprocal interaction with resilience. The term 'resilience' is the antithesis of vulnerability (Harley et al., 2008). According to McEntire (2004), the vulnerability of communities to disasters can be reduced by promoting increased community resilience. These concepts have different emphasis but collectively function in a complementary fashion (Zakour & Gillespie, 2013) to facilitate our understanding of susceptibility to hazards and the capacity to recover from such adversities. Resilience measures the adaptive capacity of a system and its capability of self-renewal and reorganisation (to cope with adverse consequences. In ecological and disaster studies, resilience refers to the capacity of a society to survive by resisting and absorbing the forces that cause disaster as well as the ability to prepare to resist future shocks (Manyena, 2006; Avallone, Baumeister & Sadegh., 2007; Alexander, 2012; Harley et al., 2008). Resilience connotes the possibility of adaptation, coping and recovery regardless of collective adversity in a system (Zakour, 2010; Zarafshani et al., 2016). While vulnerability largely looks at a system's or society's inability to cope with external stressors, the concept of resilience broadly implies a system's or an individual's ability to cope with external stressors or shocks (Adger, 2006; Levina & Tirpack, 2006; Harley et al., 2008).

Theoretical framework

Theory of Disaster Vulnerability

The foundation of vulnerability theory was set by social development theorists where many of these theorists argued that community vulnerability originates from failed development and a lack of adaptive capacity within the local physical environment to mitigate the adverse consequences of hazards (Oliver-Smith, 2004; Zakour & Gillespie, 2013). The theory seeks to explain the susceptibility of individuals, groups, organisations, communities, and countries to harm from exposure to disasters and external stresses that are associated with social and environmental changes in the absence of adaptive capacities and resilience (Adger, 2006; Zikour & Gillespie, 2013).

Vulnerability to disasters occurs when individuals or groups of people possess deficient real income, wealth and other resources to cope with emergent disaster, and when other previously held capacities and endowments are broken down (Adger, 2006). This theory is premised on the assertion "that disasters result from social causes with the people most susceptible to disasters being geographically clustered together; that is, geographic patterns of vulnerability reflect social patterns of stratified resource distribution and social inequality" (Zakour & Gillespie, 2013, p.115).

The theory further states that the vulnerability of a community to disaster is non-uniformly and unevenly distributed throughout nations or regions of the world and even within groups and within communities (Johnson & Brell, 2012; Aulong & Kast, 2011; Zikour & Gillespie, 2013). As indicated by Diaz, Hurlbert and Warren (2016), vulnerability is a fluid process. This is because vulnerabilities and adaptive capacities of communities are unevenly distributed and varies from place. Within the ambit of the theory of vulnerability, it can be argued that farmers' vulnerability to drought is not evenly distributed across regions but varies according to various geographic contexts. Even within one community or nation, the degree of drought vulnerability is not likely to be same (Brooks, Adger & Kelly, 2005; Smit & Wandel, 2006; World Bank, 2010; Zarafshani, et al., 2016).

There are 12 general assumptions that underpin vulnerability theory. These assumptions are summarized and presented in Table 1.

Table 1: Assumptions underlying vulnerability theory

1. Vulnerability of social systems implies its reduced capacity to adapt to prevailing environmental circumstances
2. Vulnerability is a multi-dimensional concept
3. Vulnerability is not evenly distributed among people or communities
4. The availability and equitable distribution of resources in a community builds resilience and decreases disaster vulnerability
5. Vulnerability is largely the result of environmental capabilities and liabilities
6. Biological, demographic, psychological, and social factors are associated with level of vulnerability. However, these do not cause disaster and vulnerability
7. Precarious circumstances in which people live and work are the most proximate and immediate societal causes of natural hazards
8. Ultimate and root causes trigger vulnerability
9. Dynamic pressures affect deep-rooted societal causes which in turn increase disaster vulnerability
10. Environmental capabilities, liabilities, and disaster susceptibility intricately act to produce the vulnerability level of a community
11. Disasters do not have a single factor or single type of factor, but occur because of a chain of factors
12. Culture, ideology, and mutual meaning are central to the progression of disaster vulnerability

Source: Zakour & Gillespie (2013)

Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) was proposed by Ajzen (1985) as an extension of the theory of reasoned action to explain the intentions that motivate an individual to act and respond in a planned way. The theory generally presupposes that human attitudes and actions have underlying reasoned intentions and processes. The central factor in the performance of a given behaviour is the intention behind it. Thus, intention serves as the motivational factor that determines whether an individual will perform a given task or not (Ajzen, 1985; 1987). According to TPB, behaviour is the observable, manifest response and action in a particular situation in relation to the attainment of targets (Ajzen, 2006). The theory explains that people's behaviour is deliberate, planned and can be influenced. In line with this theory, a planned behaviour is a joint function of related attitude towards the bahaviour, subjective norm and perceived behavioral controls, and intentions. According to this theory, human decisions and actions are guided by three main kinds of considerations as shown in the Figure 1.

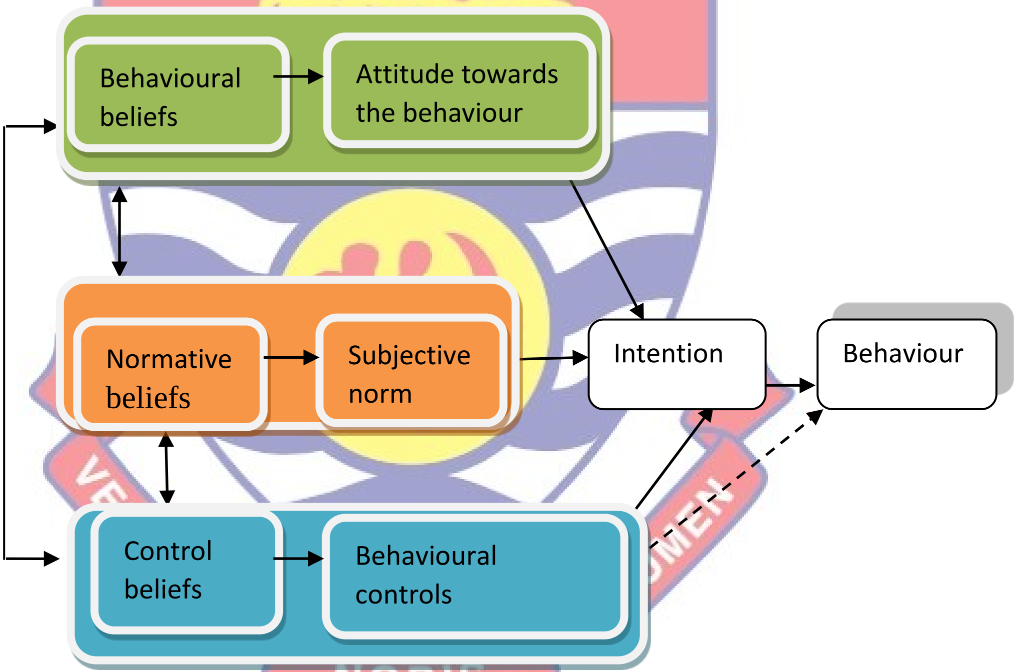

Figure 1: Theory of planned behaviour

Source: Ajzen (2006)

Behavioural beliefs: These are beliefs about the likely consequence of a planned behaviour. This will influence an individuals' attitude towards undertaking a particular action. Thus, farmers' intentions to employ some drought adaptation strategies will be influenced by their belief on the likelihood of those strategies being able to mitigate drought. Etwire (2012) asserts that most farmers would embrace an innovative idea or method if majority of them have favourable attitudes towards that innovation.

Normative beliefs: These beliefs refer to the perceived expectations of other important referent people or individuals within a social group. It is assumed that normative beliefs, in conjunction with an individual's motivation to adhere to the group norms will determine the subjective norms, intention and behaviour. Thus, people perform some actions because such actions are in line with what other people think about them (Ajzen, 2006). Farmers are likely to adopt a particular drought adaptation strategy if the strategy in question is expected to be adopted or embraced by other members of the farming communities.

Control beliefs: The theory of planned behaviour differs from the theory of reasoned action by the inclusion of control beliefs. These are beliefs about the perceived presence of other factors that may either facilitate the execution of the planned behaviour or impose constraints on the process of executing the planned behaviour. The availability of resources and opportunities (time, money, skills, cooperation of others etc) to an individual determines the likelihood of achievement of an action. The perceived power of each perceived controlling factor determines the perceived behavioural control which refers to an individual's perceived ability to perform a particular given behaviour (Ajzen, 1987; 2006).

This theory is useful for explaining farmers' adoption of drought adaptation measures. Thus, farmers' adoption decisions are influenced by other factors such as the perceived suitability and practicability of various adaptation measures. Although farmers may have intentions to respond to the impact of climate change and drought through the use of various adaptation strategies, there are several controlling factors that may either facilitate or impede their adoption process. Thus, using this theory provided the focal lens for analysing the factors that constrain farmers' capacity to adapt to drought.

Approaches to vulnerability assessment in the context of drought

Zarafshani, et al. (2016) assert that "there is no universal view on vulnerability assessment" (p. 9). This is because the concept in itself lacks a precise definition. Various researchers have developed and used different approaches to conduct vulnerability analysis. Some of these vulnerability assessment approaches are discussed as follows:

Bohle's framework for vulnerability assessment: A mixture of theories and approaches

Bohle's conceptual framework for vulnerability analysis is an amalgamation of theories and approaches that provide a holistic and an integrated framework for analysing and explaining vulnerability. According to Bohle (2001), people's vulnerability can be adequately examined by considering coping and response capacities of the individual or system. Jawura (2013), in support of Bohle, contends that vulnerability analysis should adopt a holistic approach by examining both the external emergency of exposure and the internal capacity to cope with or adapt to the adverse effects of the contingency. The double structure of Bohle's framework is shown in Figure 2.

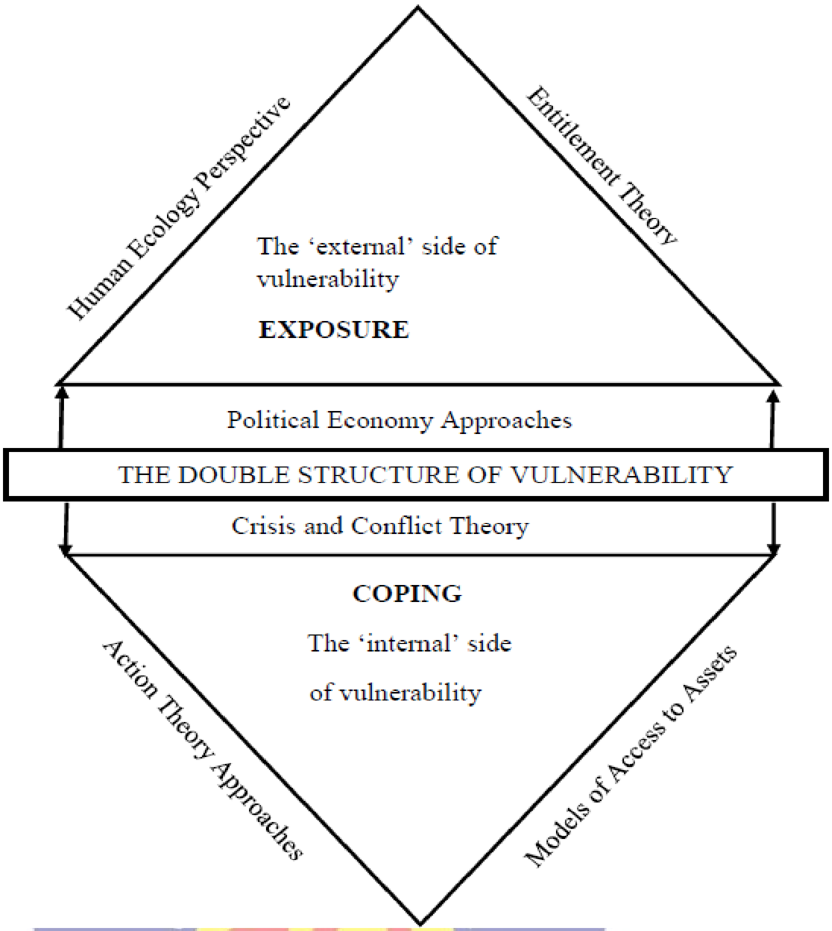

Figure 2: Bohle's conceptual framework for vulnerability analysis

Source: Bohle (2001)

From Figure 2, Bohle (2001) states that vulnerability has a double structure which composes of external and internal sides. The external side of vulnerability relates to exposure to hazardous events and shocks. This side can be influenced by Human Ecology perspective, Entitlement theory and Political Economy approaches (Bohle, 2001). From the perspective of human ecology, Bohle (2001) indicates that population dynamics and environmental management capacity influence the levels of a system's vulnerability to risks and shocks. Poorer households in disaster prone areas are more vulnerable compared to other poorer households in less hazard prone zone. This perspective emphasizes the contribution of economic growth and development in adapting to vulnerability (Adger, 2006). The conditions of vulnerability in hazard prone areas depend on the extent of exposure and susceptibility to human settlements and the environment, ecological fragilities and the poor resilience or lack of ability to anticipate, cope with as well as recovery from external risks and shocks (European Commission, 2011). Local people in the face of natural disasters need to adopt sound environmental management techniques to mitigate the resultant environmental impacts but in the absence of environmental adaptive capacity, the extent of the impact may be exacerbated.

Politically, conflicts, social inequities and unbalanced division of assets and power play a role in the existence of low or high level of vulnerability. Deliberate human actions that perpetuate self-interest and poor distribution of power or structural relations lead to vulnerability (Bohle, 2001; Adger, 2006; Gaillard, 2010) while deficient and inadequate economic growth and development processes can increase the level of vulnerability in a place (European Union, 2011). Watts and Bohle (as cited in Jawura, 2013) express their opinion on the Political Economy Approach by arguing that vulnerability is increased and perpetuated by the processes of colonialism, commercialisation, marginalisation and proletarianisation. In the context of drought, the Political Economy approach focuses on the most vulnerable group of people and why they are vulnerable. This approach emphasises that people need to be self-efficient to cope with drought. Being self-efficient is synonymous with being powerful. Therefore, less efficacious farmers are somewhat seen as powerless farmers who cannot efficiently cope with drought (Zarafshani, et al., 2016). This approach emphasises only the adaptive capacity of farmers and neglects their exposure and sensitivity to drought.

In the opinion of Bohle (2001), the Entitlement theory links vulnerability to people's incapacity to utilize the necessary legitimate economic means to obtain or manage assets. Entitlements are the available real resources possessed by individuals (Adger, 2006) and also comprise 'the set of alternatives bundles of commodity that a person can command in a society using the totality of rights and opportunities that he or she faces' (Sen, cited in Shitangsu, 2013). The resource potential of individuals influences their adaptive capacity. Thus, people who possess resources/assets are less vulnerable to environmental hazards and stressors. Vulnerability to external shocks occurs when individuals possess inadequate real income and wealth, or as a result of a failure and collapse in their previous endowments (Shitangsu, 2013).

From Figure 2, the internal side of the structure of vulnerability deals with the capacity of a system or people to anticipate the occurrence of a hazard, as well as cope with, withstand and recover from the effects of a disaster. The capacity to respond to and deal with an exposure in the short-term is known as coping and its flip side is resilience (Jawura, 2013). Bohle's framework indicates that the coping capacity, adoption of adaptation and coping strategies are influenced by Action theory approach, Models of access to assets and Crisis and Conflict theory (Bohle, 2001).

Crisis and Conflict theory states that an individual's ability to control assets and resources to manage crisis situation and resolve conflicts forms part of his/her capacity to cope with the exposure (Bohle, 2001). Thus, individuals and groups at large need to economically and effectively handle exposure to hazards and handling exposure is a skill that everybody needs to acquire, develop and practice in order to cope with such harmful situation. This will enhance the individual's capacity to cope with exposures. This presupposes that coping with drought is similar to resolving crisis and conflict and that farmers need to possess the skills and abilities to adapt to drought.

Action theory approach implies that people who are exposed to a hazard should be able to translate their knowledge, skills and resources into actions and practices that will help them to adapt to the adverse situation. This relates to what individual people and groups of people do by way of acting and freely reacting in moments of socio-economic or governmental challenges (Bohle, 2001). According to Adger (2006), human vulnerability to insecurity can almost always be prevented by human engagement, modified by political interventions and behaviour. It can be inferred from the perspectives on the action theory approach that farmers in the face of drought need to act and react in order to deal with the situation.

Models of access to assets imply that people need access to assets and resources in order to mitigate the impact and reduce their level of vulnerability to a hazard (Bohle, 2001). The diversity of economic means, community wealth and equal distribution of resources determines the capacity of people to deal with external shocks (Norris et al., 2008; Zakour, & Gillespie, 2013). The presence of adequate resources is essential for building and improving community disaster resilience. Moreover, the availability of credit facilities, society's level of wealth, institutional capacity, and access to resources and technology determine the adaptive capacity of people (Burton et al., 2006; Simpson, et al., 2008) and in the absence of these assets, victims of natural disasters may be constrained to effectively cope with the adverse effects of the disaster and this may even exacerbate their existing level of vulnerability.

Bohle's (2001) vulnerability assessment approach offers an elaborate framework for measuring farmers' exposure to drought as well as how they cope with the exposure. The approach can serve as a lens for analysing farmers' capacity to cope with drought. However, the framework does not identify the portfolio of assets and resources that are useful for assessing an individual's adaptive capacity. Moreover, the framework places much emphasis on exposure and coping and neglects the sensitivity component of climate change and drought vulnerability.

Sustainable Livelihood Framework (SLF)

The search for a complete and comprehensive framework for assessing adaptive capacity led to the formulation of the SLF. Unlike Bohle's (2001) vulnerability assessment approach which focuses on coping rather than adaptation and adaptive capacity, the SLF provides a portfolio of resources (capital) that can be used to assess people's adaptive capacity. The SLF, as developed by DFID (1999) and elaborated by Ellis (2000), among others, is a people-centred analytical tool used to determine people's strength (asset or capital endowments).

The framework advocates that there are several factors and forces that affect individuals' adaptive strategies and livelihood outcomes, and these factors and forces are constantly changing (DFID, 1999; Ellis, 2000). This framework has been utilized by various researchers (Adepetu & Berthe, 2007; Amusa, Okoye & Enete, 2015; Antwi-Agyei et al., 2012; Gbetibouo, Ringler & Hassan, 2010; Apata, 2011) to quantitatively analyse farmers' adaptive capacity to mitigate climate change and variability in the African context. The results of those studies have made significant contribution to knowledge and understanding of climate change vulnerability and adaptation. However, there is paucity of studies that employed this framework to analyse farmers vulnerability and adaptation to drought in the Ghana context.

The DFID framework which identifies people's livelihood capacity is built on five critical assets or 'capitals'. These asset categories are human, social, natural, physical and financial. Access to these assets can be either ownership or right to use and this can support people's livelihood. Households with limited assets have limited range of adaptive strategies and therefore highly vulnerable to drought (Adepetu & Berthe, 2007). Moser (as cited in Antwi-Agyei, et al., 2012) asserts that people who possess more of these assets have high adaptive capacity and therefore less vulnerable

Human assets: The DFID emphasizes that improved access to quality education and training, information technologies, better nutrition and medical health can strengthen people's capacity to adapt to hazards. In the context of drought vulnerability, farmers with sufficient level of formal education may have knowledge and skills. This can enhance their adaptive capacity and help reduce their level of vulnerability. According to Adepetu and Berthe (2007), farmers with secondary education have sufficient knowledge and more adaptive capacity compared to farmers with less formal education. Rural farmers may not have knowledge of the availability and effectiveness of certain adaptation strategies and this can greatly impede their quest to mitigate the impact of drought. Various researchers have identified lack of knowledge, information and support from existing local institutions as barriers to local farmers' use of climate change adaptation measures (Abid et al., 2015; Apata, 2011; Fosu-Mensah et al., 2012; Maddison, 2006). In a similar vein, Abdul-Razak and Kruse (2017) used a survey questionnaire to assess the adaptive capacity of smallholder farmers to climate change in two agrarian communities in the Northern Region of Ghana. They found that farmers with formal education had high adaptive capacity while farmers without formal education had low adaptive capacity.

Social assets: Socio-cultural factors can influence people's adaptive capacity and livelihood strategies. Social networks and connectedness, family relations and group memberships are important social resources that individuals can draw on to enhance their adaptive capacity in times of hazards. A cohesive social environment characterized by mutual trust and reciprocity serves as important social capitals for helping individuals to pursue their livelihood objectives and strategies (DFID, 1999; Adepetu & Berthe, 2007). Social capital plays a critical role in farmers' adaptation to climate change (Apata, 2011). The existence of interrelated social networking can also promote farmers' adaptive capacity (Bawakyillenuo et al., 2016; Ellis, 2000; Rodima-Taylor, Olwig & Chhetri, 2012). Udmale et al. (2014) found that a number of farmers in the Maharashtra State of India lacked social and community support in their existing drought relief packages. This is because they had no social solidarity and collaboration to combat the impact of drought and hence, they committed suicides.

Natural assets: DFID describes natural assets as the stock of both tangible and intangible natural resources and services such as land, forest, water bodies, atmosphere and the entire biodiversity that are useful for productive purpose. For instance, farmers with access to naturally occurring wetlands can alternatively till such lands in the wake of drought. This can greatly reduce their drought vulnerability status compared to other farmers in different lands and other alternative natural resources.

Physical assets: These refer to basic producer goods and infrastructure that can support the livelihood strategies of individuals. Examples include access to transport and communication, pumped well, irrigation facilities, energy supplies, among others. Producer goods are equipment and tools that are used to support productive activities while infrastructure are changes to the physical environment that make individuals to work and produce efficiently (DFID, 1999).

Financial assets: These assets denote financial resources such as income, cash flows as well as stocks that enable individuals to adopt alternative livelihood strategies. Financial resources comprise credit, insurance, savings in cash, bank deposits or liquid assets (such as livestock and jewellery), cash transfer or remittances. This category of assets can be obtained from individuals and financial providing institutions and groups (DFID, 1999). For instance, Adepetu and Berthe (2007) found that individuals who receive remittances have high adaptive capacity and therefore less vulnerability to climate change.

Among others, the framework serves as a checklist for identifying the factors that affect the livelihoods of individuals and also for assessing the assets possessed by individuals (DFID, 1999). The SLF is also a flexible design which can be amended to suit local context. Besides, serving as means of respecting local opinions, using this framework to assess farmers' adaptive capacity is means of involving them in the process of defining their strength and weakness. However, using this framework requires much time and other resources which may be lacking. Finally, the framework can deliver a flood of information which may become difficult to handle.

Integrated vulnerability assessment approach: A fusion of two approaches

Unlike the individual socio-economic and biophysical approaches to vulnerability assessment, the integrated vulnerability assessment approach encompasses both the socio-economic and biophysical approaches to vulnerability analysis. The socio-economic assessment approach provides a limited view of vulnerability assessment by focusing on adaptive capacity. This approach is more suitable for identifying and measuring the asset status of communities or households. However, the biophysical approach, sometimes called impact assessment, attempts to measure the level of damage caused by a hazard on social and biophysical systems (by identifying and measuring sensitivity indicators). The biophysical approach is an end-point analysis of the impact of a hazard on a system after the hazard has occurred (Zarafshani, et al., 2016). This approach is suitable for assessing the potential impact of drought (exposure and sensitivity) but excludes adaptive capacity from the vulnerability assessment process. Like any other single approach, this approach also has its limitation since it focuses on sensitivity (physical damages) analysis. According to Nelson et al. (2010), using only biophysical approach without incorporating socio-economic modelling of adaptive capacity gives erroneous message for policy makers.

In the context of drought, the integrated vulnerability assessment approach captures the merits of the socio-economic and biophysical approaches and therefore, helps to overcome the weakness associated with the individual approaches. Unlike the individual approaches, the integrated assessment approach is more advantageous because it helps to analyse the three components of vulnerability namely exposure, sensitivity and adaptive capacity. This approach is consistent with IPCC operational definition of vulnerability as the degree of harm and susceptibility to perturbations in the absence of adaptive capacity (Tesso, Emana & Ketema, 2012; Zarafshani, et al., 2016). Consequently, in this study, drought vulnerability is being conceptualized as exposure the 'residual' socio-economic and environmental impacts that are imposed by drought on farmers in the absence of adaptive capacity. This gives a holistic measure of vulnerability which has social, economic and environmental dimensions (Ciurean, Schröter & Glade, 2013).

Conceptualizing vulnerability in the context of drought

In the context of drought, vulnerability implies the susceptibility of an individual or a community to the negative socio-economic and environmental impacts of droughts and other drought-related events in the absence of adaptive capacity. Drought vulnerability may occur when a community has no or low adaptive capacity and resilience to mitigate the adverse effects of drought. In the context of this study, drought vulnerability is defined as drought exposure, the socio-economic and environmental impacts of drought minus farmers' capacity to adapt to drought.

The main ideas and perspectives from literature are fused and blended to serve as the conceptual framework to guide this study. Drought serves as the vulnerability context which is external. Drought exposure determines farmers' sensitivity and adaptive capacity. Figure 3 depicts the complex interrelationship among the occurrence of drought, farmers' vulnerability (as measured by exposure, sensitivity and adaptive capacity) and the factors (farmers' assets/capital base) that determine their adaptation response.

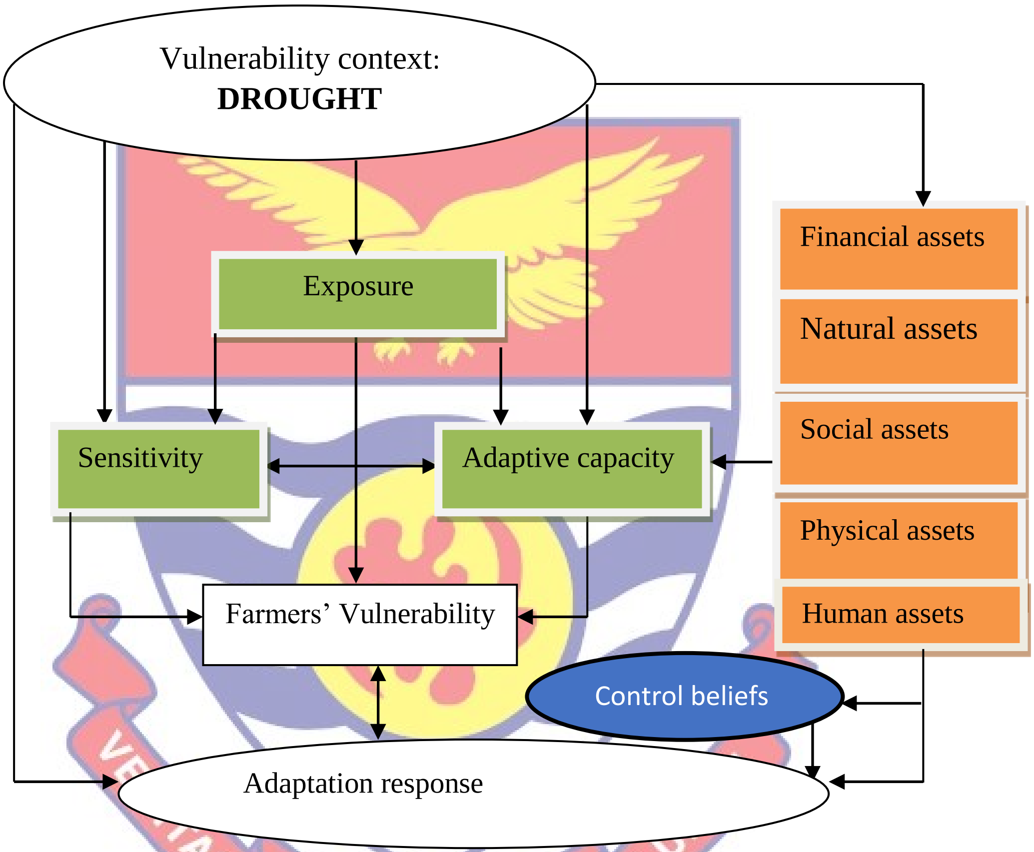

Figure 3: Integrated assessment framework on farmers' vulnerability and adaptation to drought

Source: Adapted from DFID (1999), Ellis (2002), and IPCC, (as cited in Zarafshani, et al., 2016)

From Figure 3, drought serves as the vulnerability context which is external and thus, lies outside people's control. The key drivers of farmers' vulnerability comprise exposure, sensitivity and adaptive capacity. Farmers' vulnerability is dependent upon drought exposure (defined as the severity and frequency of drought). When drought occurs, farmers become vulnerable and are likely to suffer loss or damage depending on their ability to adapt to and cope with the situation. Farmers' sensitivity deals with the question of how they are adversely affected by drought while their adaptive capacity determines how they will cope with drought (exposure).

Moreover, the extent to which farmers in a particular geographical context are vulnerable to drought is determined by farmers' economic, socio-cultural, psychological, technical and infrastructural conditions which are collectively determined by their asset possession (IPCC, 2001; Zarafshani, et al., 2012; Zarafshani, et al., 2016). Similarly, drought can also impose its rippling harmful effects on the capital base of farmers and therefore, directly or indirectly harm their resource/capital base. For instance, drought can destroy fertile farmlands, and cause the drying up of wetlands. The occurrence of drought can erode the social capital base of farmers through migration and disruption of social networks. During drought, more especially agricultural drought, soil moisture becomes deficit and insufficient to meet the demand of crops for water supply. This situation reduces the quantity and quality of crop yield. As a consequent, food supply will diminish. Where and when there is a reduction in the amount of rainfall and other forms of precipitation, plant growth will also reduce leading to a simultaneous reduction in the supply of feed for animals. This will ultimately lead to migration of farmers from one location to another in search of alternative livelihoods. These assets can serve as control beliefs which can promote and hinder farmers' adaptation response in the wake of drought.

Drought can reduce pastoral productivity through outbreak of diseases and pests and destruction of crops and livestock. Research has shown that the occurrence of droughts is linked with the deterioration of livestock production. Frequent drought leads to high incidences of some livestock diseases and mortality, changes in herd structure, and subsequent disorder in livestock markets (Speranza, 2010; Opiyo et al., 2015). Drought leads to deterioration of crop and livestock production and this in turns affects the availability of and access to food supply and security. Thus, besides food insecurity, drought can also impose severe socio-economic and environmental impacts on the livelihood of farmers.

In this study, the selection of vulnerability indicators was based on the integrated assessment approach which combines the socio-economic and biophysical approaches to vulnerability assessment. This approach was followed because it enabled me to do a comprehensive analysis of all the three components of vulnerability namely exposure, sensitivity and adaptive capacity.

Figure 3 also shows that drought vulnerability is determined by farmers' adaptive capacity. In the context of drought planning and management, adaptive capacity refers to the effectiveness of a system in mitigating the direct and indirect consequences of drought (Abraham, 2006). Households' decision to adapt to drought and utilization of forms of climate change adaptation strategies is influenced by institutional and political factors (World Bank, 2010; Bawakyillenuo et al., 2016), their asset or capital base (be it economic, human, financial, physical), and mediated by their social status (Bawakyillenuo, et al., 2014; Yaro & Hasselberg, 2016).

Farmers' adaptive capacity is closely linked with their asset possession. Moser (as cited in Antwi-Agyei et al., 2012, p. 325) argues that "people who have more assets (financial, human, natural, physical and social) are generally considered to have a higher adaptive capacity and therefore less vulnerable". Farmers' access to assets was used as a proxy to measure their adaptive capacity. Households' asset possession has hypothesized inverse relationship with their vulnerability status. These variables, therefore, influence farmers' adaptive capacity to fight drought. In this research, farmers' subjective self-assessment of the frequency and severity of drought served as the proxy variables for drought exposure. On the other hand, the socio-economic and environmental impacts of drought formed the lens for analysing drought sensitivity. The approach adopted in this present study harmonizes with Wilhite's (2011) assertion that drought impacts are the key indicators of drought vulnerability and drought vulnerability assessment should focus on analysing the impacts of drought. The degree of farmers' vulnerability to climatic-induced drought is as a result of drought impact on farmers' crop and livestock production, their socio-economic activities as well as the physical environment. In this study, the socio-economic and environmental impacts of drought are collectively termed as drought sensitivity.

Furthermore, this current study adopted DFID (1999) sustainable livelihoods framework in selecting the indicators to measure adaptive capacity. Farmers' adaptive capacity is mostly being conceptualized as a function of their five assets possession (Antwi-Agyei et al., 2012; Gbetibouo et al., 2010). The asset base of farmers serves as control beliefs which can either facilitate or hinder farmers' adaptation response. For instance, rural farmers who in the absence of social networks and group supports; and lack the necessary technical knowledge and skills on drought recovery methods are less resilient to the negative impacts that result from drought and therefore, likely to be more vulnerable. The presence of strong kinship and social network does not only lead to greater political influence but may increase a system's adaptive capacity by allowing greater access to economic resources, increasing managerial ability, providing supplementary labour and psychological comfort. Similarly, the existence of economic resources may facilitate the implementation of new adaptation technologies as well as ensure access to training opportunities (Smit & Wandel, 2006).

Finally, Figure 3 depicts that drought vulnerable farmers have to take behavioural actions in response to their vulnerability status. This action is termed as adaptation response which can be critically conditioned by certain control beliefs. A study by Mabe et al. (2014) has shown that various factors such as marital status, experience of farmers, farm income, access to phones and weather information, mixed farming, and farmers' assumption concerning reduction in the amount of rainfall affect farmer's choice of particular climate change adaptation strategies. However, the adoption of adaptation strategies may be contingent upon a specific climatic event and hence, there is the need to examine the adaptation strategies that are used to address the impact of drought in Ghana.

Concept of drought

Drought is the least understood and most underrated climatic disaster (Sheffield & Wood, 2011). Drought has been conceptualized and defined in dozens of ways depending on the affected sector, its frequency and severity.

Drought is not an abnormal climatic event (Maliva & Missimer 2012), but a normal, recurring, temporary aberration climatic event that occurs virtually in all climatic regimes of the world (Hisdal & Tallaksen, 2000; WMO, 2005; 2006; Wilhite, 2011; WMO & GWP, 2016). The occurrence of dry and wet periods are normal features of the hydrological cycle, but drought differs from aridity which is associated which low rainfall areas and constitutes a permanent feature of climate in such areas (WMO, 2005). However, arid regions are highly prone to drought and may be severely harmed by drought impact more than any other region (Maliva & Missimer 2012).

The concept of water scarcity has received considerable attention and it is often being confused with drought. Perhaps, this owes to the fact that most definitions of drought consider moments of limited water availability in comparison to normal precipitation as drought (Wilhite, 2011; Wandel, Diaz, Warren, Hadarits, Hurlbert & Pittman, 2016). Although water scarcity can be a consequence of climate change and drought, water scarcity occurs when there is excess of water demand over the available water supply. The prevailing institutional arrangements, prices, and over-development, mal-allocation or over-distribution of available water resources can cause water scarcity even in the absence of drought. Elements of human interference and mismanagement contribute to shortage of water supply (Hisdal & Tallaksen, 2000; Sivakumar et al., 2011).

Drought has no well-defined onset and end. It is a creeping climatic phenomenon. Drought declaration is arbitrary. It has multiple conceptual, and non-structural dimensions with various degrees of timings and severity (Sivakumar, et al., 2011). Wilhite and Glantz (as cited in Hisdal & Tallaksen,

2000) emphasize the need for different definitions of drought since it affects different sectors of the society in various ways. Wilhite and Glantz (1985) made seminal contribution by categorizing the definitions of drought into conceptual and operational. Conceptual definition seeks to enhance people understanding of the concept and may be important for drought policy-making and management. In line with the conceptual definition, drought can be defined as a protracted period of precipitation deficit resulting in excessive loss of crop yield; deviation of precipitation from the 'normal' or period of less than normal water supply to meet water demand. Conceptually, Maliva and Missimer (2012) define drought as period with less than normal water supply that affects human activities.

Operational definition of drought attempts to identify the onset, duration, severity and end of drought episodes. Drought is often classified based on the timing and effectiveness of rains. Operational drought is associated with water resource indicators which measure the severity of the impact of drought on the availability of water resources for domestic, industrial and agricultural purposes (Hisdal & Tallaksen, 2000; UNESCO, 2007; Wilhite, 2011). This definition poses a difficulty in attempt to understand drought because knowing when drought begins is difficult and whenever it begins, its duration and severity are unknown (UNESCO, 2007). Generally, drought is marked by the absence of rainfall, late or too early onset of inadequate rain (Gebrehiwot, Veen & Maathuis, 2011). To understand operational drought, WMO recommends the need to compare the current situation with 30-year historical averages of precipitation records (Sivakumar et al., 2011; WMO, 2006).

Classifications of drought

There are four types of drought based on the affected sector. These include meteorological drought, hydrological drought, agricultural drought and socio-economic drought.

Meteorological drought: It is defined as the degree of dryness or departure of precipitation in comparison to the long-term normal or average precipitation conditions. This definition reflects the main cause of drought as climate-related. Definitions of meteorological drought must be region-specific since the atmospheric conditions that result in precipitation deficiency vary from region to region (Maliva & Missimer, 2012; Wilhite & Glantz, 1985; Wilhite, 2011).

Hydrological drought: This occurs when periods of precipitation deficiency affect availability of surface or subsurface water supply (i.e., reservoir, lake levels, stream flow, and groundwater). Hydrological drought reflects the impact of meteorological drought. The severity and frequency of hydrological drought is defined on water basin or watershed. However, changes in land use patterns, deforestation and desertification, construction of dams and all forms of environmental degradation affect and contribute to hydrological drought (Wilhite, 2011; Maliva & Missimer, 2012, Wilhite & Buchanan-Smith, cited in Diaz, Hurlbert, & Warren, 2016).

Agricultural drought: Agricultural drought is a manifestation of the various characteristics of meteorological and hydrological droughts on level of agricultural productivity. It links the various forms of drought to agricultural impacts, focusing on precipitation deficit for crop and animal production, gap between actual and potential evapo-transpiration, reduced soil water and moisture content, reduced groundwater or reservoir levels for agricultural use, among others (Mishra & Singh, 2010; Wilhite & Glantz, 1985; Wilhite, 2011). Agricultural drought should form the starting point for drought vulnerability assessment (Žurovec, Cadro, & Sitaula, 2017).

Socio-economic drought: This occurs whenever there is insufficient water supply to meet the socio-economic demand for water. This type of drought links elements of human activities with the other types of drought (Wilhite & Glantz, 1985). It refers to moment of imbalance between the supply and demand of water as an economic good. Thus, it shows failure in water supply system to satisfy water demand (Mishra & Singh, 2010; Wilhite, 2011).

Climatologically, drought is often caused by climate change natural climate variability. The various classifications of drought are highly interdependent. Where there is precipitation deficiency as a result of natural climate variability, meteorological drought may occur. Meteorological drought leads to limited water supply, reduction in infiltration and percolation rates, as well as groundwater discharge. High temperature and sunshine, low relative humidity and less cloud cover are the consequences of natural climate variability and these conditions lead to high evapo-transpiration. Increased evaporation and transpiration rates coupled with deficient precipitation cause agricultural drought where there is deficient soil moisture and subsequent stress in plant life, reduction in biomass and crop productivity (Maliva & Missimer 2012).

Rainfall pattern in Ghana

Numerous models (Water Resources Commission, 2010; McSweeney, New & Lizcano, 2012; Kankam-Yeboah, Obuobie, Amisigo & Opoku-Ankomah, 2013 etc.) have predicted that rainfall amounts would decline in various agro-ecological zones and river basins of Ghana in the long-run. This has the tendency of causing droughts which have serious implications on agricultural productivity and food security in the country (Baidu, Amekudzi, Aryee, Annor, 2017; Nkrumah et al., 2014; Owusu & Waylen, 2009).

There are variations in climatic patterns in the savannah ecosystem of Ghana. A national study conducted by Opoku-Ankomah and Cordery (cited in Owusu, 2009) suggests that there is distinct rainfall variability in the savannah zone which receives less rainfall amounts compared to other agro-ecological zones in the country. The spatio-temporal variation in climate results in periodic droughts and floods in the savannah belt (Yiran & Lindsay, 2016). A trend analysis in precipitation in Tolon and Kumbungu districts within northern Ghana by Nyadzi (2016) shows that rainfall is characterised by inter-annual and monthly variability with the year 1970-1979 recording the highest rainfall followed by 1990-1999, 1980-1989 with 2000-2009 which received the lowest precipitation. This analysis clearly shows that trends in precipitation in parts of northern Ghana are declining. Monthly rainfall gradually increases from March with interruptions in June or July until it reaches it maximum peak in August or September and abruptly declines thereafter (Owusu, 2009; GMeT, 1998 – 2016). This is confirmed by results of a study by Nyadzi (2016) that June to September usually records the highest rain fall amounts in Ghana.

Owusu (2009) has indicated that the mean annual rainfall totals within southwestern forest agro-ecological zone has experienced a decline. However, parts of Ashanti and Western Regions of Ghana receive higher mean annual rainfall exceeding 1,900 mm (Logah, Ofori & Kankam-Yeboah, 2014). GMeT (1998 – 2016) reports that double rainy seasons in the forest areas experiences highest in May or June and in October. Rainfall amounts are similar in all months although December, January and February, and July, August and early September, are generally less wet compared to other months.

Generally, rainfall exhibits bi-modal nature in the middle and southern belts of Ghana (Nkrumah et al., 2014) while the Savannah zone has uni-modal character. Generally, rainfall amounts have decreased in the transitional agro-ecological zone. Mean rainfall amount has decreased over 1968-1989 climatological period but increased between 1990-2011 (Quagraine, Klutse, Nkrumah, Adukpo & Owusu, 2017). This spatio-temporal variation in rainfall results in differential timing and intensity of drought across various agro-ecological zones.

Empirical review on climate change and drought impact and vulnerability

The nature, intensity and impact of drought vary from location to location relative to the prevailing geo-physical, agro-climatic, and socio-economic conditions (Swain & Swain, 2011). Changing climatic patterns are causing drought-related disasters, leading to disruptions in hydro-electric power generation, loss of property, and reduction in economic growth in Africa (World Bank, 2010) as well as poverty, food insecurity, and displacement of people (Amponsem, 2015). Drought impacts are broadly categorized as social, economic and physical/environmental (Coleen, Laing & Monnik, 2006; WMO & GWP, 2016).

Results of research on drought vulnerability have shown that drought has ramifications for all social groups and it affects "social activities, and social processes in different forms and with different consequences" (Wandel, Diaz,Warren, Hadarits, Hurlbert, & Pittman, 2016, p. 16). Drought indirectly fosters desertification, ecosystem destruction, environmental degradation, habitat fragmentation and decreased household welfare as well as reduction in prices of crop and livestock. The indirect effects of drought are usually felt larger and more pronounced than its direct effects (IPCC, 2014; Udmale, Ichikawa, Manandhar, Shidaira & Kiem, 2014). Lin, Deng and Jin (2013) asserted that loss of agricultural harvest is a direct impact of drought. Drought directly affects agricultural production, lives and health of people, their livelihoods, assets and infrastructure that consequently lead to food insecurity and poverty. Similarly, drought impact on agriculture is felt through high evapo-transpiration and reduction in soil moisture. The level of drought severity and the resultant soil moisture deficiency determine the extent of drought impact on agriculture (Polthanee, Promkhumbut & Bamrungrai, 2014).

Furthermore, scholars in the field of climate change and variability believe that drought as a natural hazard yield both positive and negative results. Some may derive benefits from drought while many others incur loss in moments of drought (Chhinh, 2015; Zarafshani et al., 2016). With regard to its positive effects, Zarafshani, Zamani and Gorgievski-Duijvesteijn (2006) applied the Theory of Conservation of Resources to study the effects of drought among farmers in Iran. They found that farmers perceived drought as a mixed blessing: either as a threat to their resources or as an advantage and opportunity to obtain more resources. Thus, during periods of droughts, the farmers managed to secure more access to credit facilities so as to rejuvenate their wells or establish pressurized irrigation systems. Zarafshani et al. (2005) found that almost all farmers who lost their material resources also gained personal and social resources (patience, hope, and strengthened social network, knowledge, skills, self-efficacy, mastery, control and social support). Similarly, Kromker and Mosler (cited in Zamani, Gorgievski-Duijvesteijn, Zarafshani, 2006) discovered that some people even embraced drought as a moment to promote and support societal value, such as group coherence and aid programmes. The farmers indicated that drought made them to suspend the necessity of undertake tiring and tedious fieldwork, whilst food provision was obtained through food aid. Zamani et al. further argued that rich people in farming communities seldom starve. However, with the on-set and even after drought, wealthy merchants are able to buy various means of production. Livestock is bought at very low prices and people are hired as labour at depressed wage rates. This study highlights that drought offers both opportunities and disturbances to Iranian farmers. However, there would be the need to use the mixed methods approach to investigate farmers' degree of vulnerability to drought and the various drought adaptation methods being used in Ghana.

In Maharashtra state in India, Udmale et al. (2014) sought to understand rural farmers' perceived socio-economic and environmental impact of drought. These researchers interviewed 223 farming households to collect primary data. The results showed that drought poses immediate economic impacts such as reduction in the yield of cereals and horticultural crops as well as decrease in livestock production and loss of employment. Socially, the rural farmers also revealed that drought posed health implications, population migration, farmers' suicide, and sense of hopelessness, conflict for water, malnutrition and drop out among school children. These socio-economic and psychological impacts of drought were associated with declining income and living standards for the agrarian households. The study also found that drought posed such environmental impacts as extreme heat and temperature, forest and pasture degradation, decline in groundwater aquifers and water quality, as well as damage to fish and wildlife habitat.

Similarly, Shiferaw et al. (2014) also reported in their study on managing vulnerability to drought and increasing livelihood resilience in SAA that drought resulted in social, economic and environmental impacts on regions and countries. According to Shiferaw and associates, drought imposes huge socio-economic and environmental impacts on countries in SAA and the overall economic and developmental success already gained is being threatened by the national costs and losses associated with drought planning and management. It was also found that drought threatens food production, food and nutrition security and contributes largely to malnutrition and famine in SAA. Increased food prices, increased in livestock diseases and mortality, loss in crop productivity, reduced water levels, wildlife and fish mortality, environmental degradation, low income for farmers and agribusinesses, widespread of diseases and insect infestation, rampant conflict and human outmigration are all associated with drought conditions (Makoka, 2008; Shiferaw et al., 2014). However, drought conditions might result in different socio-economic and environmental impacts in Ghana.

In another study, Amusa, Okoye and Enete (2015) employed the adaptive capacity approach to assess gender-based vulnerability and contributions to climate change adaptation decisions among farming households in Southwest Nigeria. It was found that female headed farm households had higher climate change vulnerability index (0.73) compared to male headed farm households which had relatively lower vulnerability index (0.43). The study also revealed that vulnerability to climate change was zonal-based. Farming households in the Derived Savanna Zone (Ekiti State) scored 0.61 on the vulnerability scale while the Rainforest Zone (Ogun State) had the least vulnerability index (0.53). The Guinea Savanna Zone (Oyo State) had the second highest vulnerability score of 0.60. The higher vulnerability among female-headed households was due to their limited access to education, land, training and other farm resources. Although the study highlighted various factors that contributed to farmers' adaptive capacity as well as barriers to climate adaptation, the approach is flawed because it did not assess farmers exposure and sensitivity which together with adaptative capacity contribute climate change vulnerability.

Furthermore, Agyei- Antwi et al. (2012) conducted a quantitative study to assess the sensitivity of crop production to drought in Ghana by using secondary data. They sought to identify regional and inter-regional drought sensitivity difference across Ghana. The study was constrained by limited socio-economic data and monthly rainfall data, loss of maize harvest, literacy rates (%) and financial capital endowments rates (represented by poverty rates) were the only proxy variables used. The researchers acknowledged that the approach was a simplified assumption. The study made significant contributions and revealed that generally, Ghana is vulnerable to drought. It was found that half of the regions in the country exhibits medium vulnerability to drought whereas a third is highly vulnerable and only two regions have low vulnerability. The study revealed that Northern, Upper West and Upper East regions are the most vulnerable to drought while the lowest vulnerability regions consisted of Ashanti and Greater Accra which are the most developed and urbanized regions in Ghana. However, the study was limited to drought impact on crop productivity but drought is a 'wicked' problem and its impact spans across various sectors. Similarly, the secondary data used as proxy variables to analyse drought vulnerability did not reflect a complete nature of exposure, sensitivity and adaptive capacity components of drought. Moreover, the results of the study only showed the degrees of regional vulnerability to drought but did not provide insights on how farmers adapt to drought.

Moreover, Jawura (2013) employed both quantitative and qualitative techniques to investigate the impact of drought on migration intentions among 279 households in the Savelugu-Nanton district in Northern Ghana. The study found that although reduction in crop yield is the commonest effect of drought, some members of the Savelgu-Nanton district also resorted to seasonal outmigration as a consequent of drought. Similarly, immobility and return migration were also associated with drought regimes. This is because past unpleasant migration experiences might discourage rural households from embarking upon migration during drought. It is obvious that Jawura's (2013) study revealed conflicting results on how drought impact on migration and displacement and concluded that drought vulnerability does not constitute a sufficient condition for migration and displacement. This is in stark contrast with other studies (Shiferaw et al., 2014; Udmale et al., 2014) which have commonly cited population migration as an impact of drought.

Asafu-Adjaye and Amikuzuno (2015) also used trade-off analysis minimum data model (TOA-MD) to estimate the socio-economic impact of climate change on smallholder farmers in the Lawra District of the Upper West Region. The researchers found that agriculture is an anti-poverty tool. However, while smallholder farmers strive to break the chain of poverty, climate change, particularly drought continuously threatens and worsens their vulnerability and emasculate their development prospect. The study revealed that climate change resulted in loss of farmer's net revenue and per capita income. This study concurs with the results of Zarafshani's et al. (2012) previous study that drought can reduce the income levels of farmers. Drought reduces agricultural income for farmers and this also increases their level of vulnerability. This is because during drought, farmers' income diminishes and this, in turn, reduces their capacity to mitigate subsequent cases of vulnerability (Zarafshani et al., 2012). However, these studies did not explore farmers' adaptive capacities which would have allowed them to have a complete gauge of farmers' vulnerability and adaptation to drought.

Climate change and drought adaptation strategies in Africa

Families whose livelihoods depend on farming activities need a variety of adaptation strategies to mitigate the harmful impacts of climate change and drought. This will help them to maintain their livelihoods (Uddin, Bokelmann & Entsminger, 2014). Adaptation serves as the means to mitigate a system's vulnerability to hazardous events. Adaptation reflects farmer's adaptive capacity. It is a process through which a society makes better adjustments and changes in order to adapt to an unforeseen situation in the future (Smit & Wandel, 2006; UNFCCC, 2011). In the context of climate change, adaptation refers to the process of adjustment to the actual or expected climate, its variability and concomitant effects (IPCC, 2014; Quandt & Kimathi, 2016). It is a means to build a system's capacity, resilience and to adjust to the impact of climate change with the ultimate aim of reducing vulnerability. It is a process through which a society makes better adjustments and changes in order to cope with an unforeseen situation in the future (Smit & Wandel, 2006; UNFCCC, 2011). It may involve adjustments in technologies, lifestyles, infrastructure, ecosystem-based approaches, basic public health measures, and livelihood diversifications to reduce vulnerability (IPCC, 2014). It may also serve as means to optimizing the potential benefits of climate change.

Adaptation strategies are numerous and their implementation processes differ from place to place. Abid et al. (2015) collected data from 450 farmers in three districts in the three agro-ecological zones in the Punjab province of Pakistan to examine how they adapt their farming to perceived climate change. According to these researchers, although farmers actually perceived changes in the climate, those farmers who employed climate change adaptation techniques were considerably less than those who did not adapt to the risky climate changes. However, in the midst of attempting to adapt, some farmers also develop and hold a fatalist and optimistic perspective. This perspective poses a major barrier to farmers' adaptation planning (Pardoe et al., 2016). Farmers with previous experience of failure in adaptation decide to be 'non-adapters' and hence, despite losses from drought over the previous years, they have decided not to adapt all. These farmers harboured the belief that 'God will make a way for them.' They adopted adhoc short-term measures to manage the situation instead of adoption of planned adaptation strategies to combat the situation.

Numerous studies have demonstrated that adaptation strategies are numerous and their implementation processes differ from place to place (Abid, Scheffran, Schneider & Ashfaq, 2015; Balama, Augustino, Eriksen, Makonda & Amanzi, 2013; Etwire et al., 2013). Through research, diverse strategies have been identified as appropriate mechanisms that assist people to adjust to climate change and drought. For instance, Fosu-Mensah et al. (2012) have discovered that diversification of crops, cultivation of short season crop varieties, changes of crop species, as well as changes in planting calendar are considered as the main climate change adaptation strategies used by rural farmers in the Sekyeredumase district of the Ashanti Region of Ghana. Similarly, a study conducted by Mabe et al. (2014) discovered that changing crop species and planting dates, afforestation and reforestation, destocking, increasing the size of farm lands, fertilizer application, fallowing of farm land, crop diversification and mulching were adopted by farmers as climate change adaptation strategies in Northern Ghana. Rural farmers in local communities in Africa have been adapting to extreme climatic events in order to ensure sustainable food production through the use of local strategies. These local strategies used by rural farmers in Africa consist of crop diversification; intercropping, home gardening, diversifying herds and income activities (such as the introducing replacing goats with sheep); prevention of soil erosion, increasing tree densities through pruning and fertilizer application, as well as use of organic manure (UNFCCC, 2011). The results of these empirical studies clearly demonstrate that farmers in Ghana know and use various methods to mitigate the impact of climate change. Albeit, these studies have made much contribution to the literature on climate change adaptation in Ghana but failed to examine how farmers adapt to and cope with drought.

A substantial body of literature indicates that farmers adapt to climate change and drought by using diverse strategies. For instance, survey conducted by Apata (2011) have revealed that most farmers in Southwest Nigeria have adopted one or more of these following major climate change adaptation options: planting of trees, mixed cropping and farming, soil conservation techniques, using multiple varieties of crop, irrigation techniques and changing planting calendar. Mixed cropping, followed by changing planting dates was the most adopted climate change adaptation method (Apata, 2011). However, Adesoji and Ayinde (2013) investigated the adaptation strategies employed by arable crop farmers in Osun State, Nigeria to moderate the harmful effect of climate change and it was revealed that using different planting dates, multiple cropping, and cover cropping were the most regular climate change adaptation methods. The findings of these empirical studies suggest that there are different strategies that farmers in different geographical locations adapt to mitigate the negative impact of climate change. It is also obvious from these studies that some adaptation strategies are mostly used while others are less preferred. This implies that rural farmers employ different climate change and drought adaptation methods and hence, farmers in the rural communities around other districts might also employ different preferred drought adaptation methods.

Moreover, Balama et al. (2013) employed qualitative techniques namely participatory rural appraisal, household questionnaire interviews, key informant interviews, and focus group discussion to examine local farmers' climate change adaptation strategies in Kilombero District of Tanzania. The study revealed that local farmers have developed two forms of adaptation strategies namely farming and non-farming strategies. Farming strategies used by local farmers to adapt to climate change included crop diversification (growing various food and cash crops, use of drought and pest resistant crops, changing cropping date and use of modern farming methods. However, Balama et al. (2013) noted that rural farmers near forest resources adopted climate change adaptation that differ from villages that are located far away from the forest resources.

Other measures such as conservation agriculture (ATPS, 2013) as well crops that are drought-tolerant, pest and disease-resistant crops have been adopted as drought adaptation measure (ATPS, 2013; Udmale et al., 2014). while some farmers modify their tillage practices to adapt to drought Adepetu & Berthe, 2007; Bawakyillenuo et al., 2016; Udmale et al., 2013). Similarly, research findings also showed that compost fertilization can help to improve infiltration, soil fertility, and its water retention and transmission capacity, modify its physical and hence, make crops more drought tolerant (Debnath, Deb, Sen, Pattannaik, & Ghosh, 2012; Kurothe, Kumar & Singh, 2014; Kloos & Renaud, 2014; Pardoe et al., 2016; Wani & Chand, 2013). However, non-farming adaptation strategies comprised weaving, use of forest resources, livestock production, fishing farming, and petty business, being casual workers and relying on remittances from alternative sources.

Constraints to climate change and drought adaptation in Africa

Anticipating and adapting to climate change in order to reduce or eliminate the human and environmental toll of climatic events is a significant challenge to all communities (Burton et al., 2006). This situation arises because climate change adaptation planning and implementation is contingent on several factors. This, therefore, presupposes that the existence of certain factors can either enhance or constrain the process of adaptation. Ellis (2000) asserted that farmers' capacities to absorb the impacts of climate change depend on ownership or accessibility to multiple resources. The availability of credit and insurance facilities, and government and external support programmes also determines the rate of adaptation planning and implementation. When there is limited access to these resources, the likelihood of farmers becoming defenseless is increasingly high (Ellis, 2000).

The rural poor are more vulnerable and largely unable to adapt to adverse climatic effects and this makes them more vulnerable (World Bank, 2010). Poverty essentially serves as a constraint to the adaptive capacity of farmers. This incapacitates households' ability to adapt to extreme but expected events (Fosu-Mensah et al., 2012; Jakpa, 2015; Mabe et al., 2014). Research indicates that farmers at the on-set of the rainy season cannot pay for the cost of fertilizer and seeds due to unavailability of financial resources. Although ccess to credit is found to be insignificant predictor of climate change adaptation (Uddin et al., 2014), lack of finance has been cited as the common problem that considerably hampers most farmers from adopting improved varieties of seed to combat drought (Pardoe et al., 2016).

Furthermore, Simpson et al. (2008) identified numerous barriers that impede the process of adaptation. These include priorities for scarce resources, weak institutions, inadequate infrastructure, degraded natural resources, and poor governance. Farmers must make an investment in order to adapt to and cope with drought impacts but in the wake of insufficient financial resources, rural farmers will be severely constrained to tackle drought and other climate change related events. Similarly, Bawakyillenuo et al. (2016) also found that poor and corrupt leadership and lack of fund served as constraints to farmers' non-adoption of irrigation systems, fertilization application and other drought adaptation strategies in the Savelugu Nanton, West Mamprusi and Kassena Nankana East Districts of Ghana.

In a related study, Nabikolo, Bashaasha, Mangheni and Majaliwa (2012) conducted a quantitative study to examine the determinants of climate change adaptation by using male and female-headed farm households in Eastern Uganda. The study revealed that farmers who did not implement climate change adaption practices mentioned resource-related constraints such as lack of money or credit facilities, inadequate knowledge of climate change adaptation measure, limited land, and lack of agricultural inputs. It was also found that farmers' demographic factors did play any significant role in climate change adaptation.

Moreover, other farmers stated that lack of dependable weather accounted for their inability to adapt to climate change. Most female-headed households also highlighted lack of sufficient time to implement the adaptation practices as a constraint to their adaptation planning and implementation. This could be because women usually have other domestic responsibility to fulfil and this might not permit them to have more time for farming activities. Similarly, other researchers cited limited financial resources and the poor socio-economic status of most households as the common and major adaptation barrier (Opiyo et al., 2015; Simpson et al., 2008). Even with the introduction of new and improved agricultural techniques, farmers with inadequate resources will find it difficult, if not practically impossible, to embrace such innovative practices. For instance, inadequate resources (labor, land, and cash) and high prices associated with seeds have been cited as the major reasons that accounted for farmers' inability to cultivate new drought-tolerant maize varieties (Fisher, Abate, Lunduka, Asnake, Alemayehu, Madulu, 2015).

Pastoralist households' intentions to adapt to drought are not without constraints (Opiyo et al., 2015). Opiyo et al. revealed that a number of limitations to their adaptation strategies included insecurity (50 %), inadequate cash income and capital (46 %), illiteracy and lack of technical knowledge (25 %), lack of affordable credit facilities and access (42 %), inadequate markets (10 %), and lack of inputs and equipment for agricultural practices (22%). It was also revealed from FGD with participants that some of these desired strategies, such as irrigation farming, development of water sources, and insurance for livestock assets, required an initial investment capital that is beyond the reach of many households. This limited their adaptive capacity. However, Abid et al. (2015) discovered that the major factors that constrained farmers' adaptive capacity to tackle the impact of climate change in the Punjab province of Pakistan comprised the following: lack of information (44 %), lack of money (22 %), lack of resources (17 %), shortage of water for irrigation (14 %) and other challenges (2 %).

Farmers' knowledge and awareness of adaptation strategies can influence their adaptation planning and implementation. Educated farmers are well-equipped with managerial skills to handle larger stocks of livestock without necessarily encountering the negative impacts of climate change (Mabe et al., 2014). Research indicates that lack of knowledge and understanding of adaptation practices can also constrain farmers' decision to adopt climate change and drought. Numerous studies have found that low levels of education and literacy create an impediment for farmers to understand, gain and accept new national adaptation policy, knowledge, and lifestyles (Ellis, 2000; Simpson et al., 2008; Yang, et al., 2015). Illiteracy imposes limitations on smallholder farmers' access to information, particularly from documented sources. This increases their susceptibility to climatic stresses like drought and flood (Jakpa, 2015).

Availability of and access to knowledge and information may also influence farmers' adaptive capacity. Farmers' accessibility to meteorological information on climate change through contact with extension officers or other sources creates awareness and favourable condition for adoption of farming practices for mitigating climate change (Harvey, et al., 2014; Maddison, 2006). Apata (2011) during a focus group discussion with farmers gathered that farmers lacked effective access to valuable information on climate and weather as well as access to climate change adaptation methods and this impeded their ability to adapt to climate change. Apata (2011) further found that unavailability of money or credit facilities, shortage of land and labour, and poor capacity for irrigation constrained farmers' efforts to adapt to climate change. The positions of these authors are consistent with Fosu-Mensah et al. (2012) who through an interview with 180 households in Sekyedumase District of Ghana to analyse farmers' adaptation responses to climate change discovered that lack of information on weather and adaptation strategies, and poverty are the main barriers to the implementation of adaptation measures. Drought, though a manifestation of climate change, may deserve specific different adaptation approaches and this may impose specific different constraints on farmers' adaptation response.

Furthermore, a study by Adepetu and Berthe (2007) found that inadequate extension services constrained farmers' ability to adopt soil and water conversation practices. Generally, lack of knowledge, information and support from existing local institutions have been identified as barriers to local farmers' use of climate change adaptation measures in the Punjab Province of Pakistan (Abid et al., 2015).

A study conducted by Harvey, Rakotobe, Rao, Dave, Razafimahatratra, Hasinandrianina, Rajaofara and Mackinnon (2014) also revealed that farmers in Madagascar lacked access to formal safety nets to which they could fall on in times of necessity. The study highlighted that only 2% of the 600 surveyed smallholder farmers had either a personal savings account or village saving accounts. Thus, most smallholder farmers have no access to formal credit or banking system. The researchers concluded that most farmers lacked access to credit or loan facilities and this deepened the farmers' vulnerability to climate change. Harvey et al. (2014) further found that despite the existence and operation of numerous local NGOs in selected regions in Madagascar, there was no formal extension service among farmers and only 7% of the farmers received technical support. This exacerbated the farmers level of climate vulnerability. Similarly, Opiyo et al. (2015) found that poor information access and extension services limited farmers' adaptive capacity. Rural farmers may not have knowledge on the availability and effectiveness of certain adaptation strategies and this can greatly impede their quest to mitigate the impact of drought. These barriers have greatly affected the effective implementation of drought and water shortage adaptation strategies.

In another breadth, time also serves as a barrier to drought adaptation. Society has a limited and short time frame to make decisions concerning future climate change. Thus, society lacks the capacity to plan and implement adaptation strategies on a long-time scale to reduce the effects of climate change. Inadequate time for adaptation planning results in poor adaptation planning (Wisconsin Initiative on Climate Change Impacts [WICCI], 2011). Climate change adaptation aims at providing benefits and vantage points for people in the future. However, inadequate knowledge and uncertainty about future climate change also pose a challenge to climate change adaptation. There is a high degree of uncertainty and this limits the ability of individuals to determine and predict the future climate (WICCI, 2011).

In technology studies, Isham (2002) asserts that social capital plays an important role in the adoption process. Through social capital, individuals are able to exchange information and ideas on the availability and quality of climate change adaptation strategies. The existence of interrelated social networking can promote farmers' adaptive capacity (Bawakyillenuo et al., 2016; Ellis, 2000; Rodima-Taylor, Olwig & Chhetri, 2012). Similarly, Udmale et al. (2014) found that numbers of farmer in the Maharashtra State of India lacked social and community support in their existing drought relief packages. This is because they had not social solidarity and collaboration to combat the impact of drought and hence, they committed suicides.

Chapter summary

This chapter presents a review of literature that relates to the topic under investigation. The Chapter deals with both theoretical and empirical review. It emerges from the literature that vulnerability is an elusive concept that defies a single universally accepted definition and assessment. Nonetheless, there are two competing interpretations of vulnerability namely, starting-point and end-point approach. Starting-point approach views vulnerability as the general characteristics of a system generated by several social and environmental factors and processes and worsened by climate change while the end-point approach, which has been utilized in this study, views vulnerability as the residual impact of climate change minus adaptative capacity. In the context of climate change, vulnerability connotes the level of exposure and sensitivity to climate change disaster in the absence of capacity to adapt to the harm or take advantage of the harm. In the context of this study, farmers' drought vulnerability is defined as the drought exposure, socio-economic and environmental impacts of drought minus their adaptive capacity.

The review also points out that Ghana exhibits distinct rainfall variability with the Savannah zone receiving fewer rainfall amounts compared to other agro-ecological zones in the country. The spatio-temporal variation in climate results in periodic droughts which render farming households and communities vulnerable. Vulnerable farmers respond to reduce or overcome the impacts of drought through adaptation which is influenced by their ownership of or access to various resources as identified by the SLF (human capital, social capital, natural capital, physical capital and financial capital). Thus, although farmers may have the intentions to respond to the impact of climate change and drought through various adaptation strategies such as irrigation, soil conservation practices, migration, applying agro-chemicals, mixed cropping and farming, changing planting dates, among others, the review reveals that there are several controlling factors that may either facilitate or impede their adoption process.

From the review, various theoretical and conceptual frameworks have been proposed and used to examine farmers' vulnerability and adaptation to climate change in African and the world at large. These comprise the Theory of disaster Vulnerability proposed by Zakour and Gillespie (2013), Ajzen's (1985) Theory of Planned Behaviour, Bohle's (2001) Conceptual Framework, the DFID (1999) Sustainable Livelihood Framework and the IPCC (2007) Integrated Vulnerability Assessment approaches. The results of those studies have made significant contributions to knowledge and understanding of climate change vulnerability and adaptation. However, few of these theories and frameworks have been employed to comprehensively analyse farmers vulnerability and adaptation to drought in the Ghanaian context.

Furthermore, most studies on climate change vulnerability and adaptation followed a single theoretical and conceptual assessment approach. The results of these studies did not provide a comprehensive measure, view, and understanding of farmers' vulnerability and adaptation to climate change events drought in Ghana, particularly in the selected study areas. This current study used a multi-theoretical and conceptual framework to assess farmers' vulnerability and adaptation to drought. Integrating multiple frameworks to carry out this study was aimed at providing a complete measure and explanation of farmers' vulnerability and adaptation to drought in Ghana.

CHAPTER THREE

PROFILE OF STUDY AREAS AND RESEARCH METHODS

Introduction

This chapter is in two parts. The first part is a presentation on the study areas and the justification for choice of study areas. The second part discusses the research methods that were followed to examine farmers' vulnerability and adaptation to drought in the three agro-ecological areas. The second part is devoted to a description of the research paradigm and design, population, sample and sampling procedures, sources of data, instruments, issues of reliability and validity, data collection procedures, ethical considerations as well as data processing and analysis.

Study areas

Three agro-ecological locations namely Wa West (Savannah zone) Nkoranza North (Transitional zone) and Wassa East (Forest zone) of Ghana were chosen as the sites for this study. Figure 4 depicts the selected study areas.

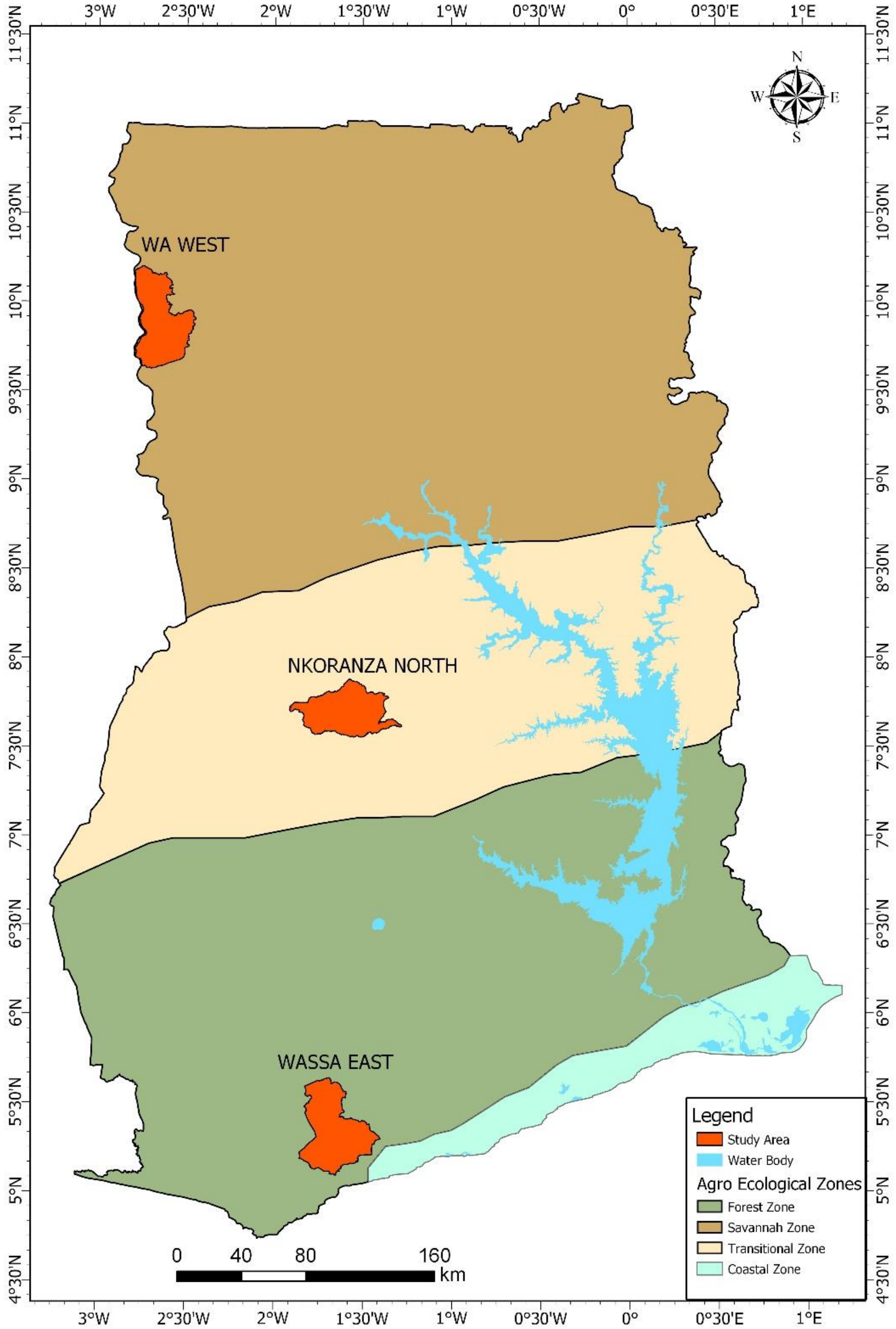

Figure 4: Map of selected agro-ecological locations

Source: Cartography, Geographic Information Systems and Remote Sensing Section (2019).

Wa West District

The district capital is Wechiau, about 15.0 km away from Wa Municipal. WWD is located in the western part of the Upper West Region, approximately between longitudes 9^0 40' N and 10^0 10' N and also between latitudes 2^0 20' W and 2^0 50' W. It is found on the Savannah High Plains which generally have undulating topography with average height between 180 and 300 meters above sea level. Politically to the south, it shares boundaries with the Sawla-Tuna-Kalba District in the Northern Region, Nadowli-Kaleo District to north-west, to the east by Wa Municipal and to the west by Burkina Faso. The landmass of the area is approximately 1492.0 km^2 (WWDA, 2012; GSS, 2014).

The geological formation of the district consists of predominant pre-cambrian granitic and metamorphic rocks that have undergone less weathering as a result of low rainfall, less vegetation cover and high evapo-transpiration. The area is mainly drained by the Black Volta and its seasonal tributaries (GSS, 2014). The river system provides opportunity for irrigation but this has not been utilized, possibly due to limited technology and its seasonal characteristics.

Sandy loamy, clayey loamy and loamy soils are the main soil formations in the area. There are also strips of grayish brown alluvial soils along the alluvial plains of the Black Volta. However, most of these soils have poor water balance and moisture conditions (GSS, 2014; WWDA, 2012).

The area is characterized by the dry equatorial continental climate. The district is semi-arid with two distinct seasons namely, the wet and dry seasons. The rainy season (between April-October) is caused by the South-Western

Monsoon winds from the Atlantic Ocean while the dry season (between November-March) is caused by the dry North-Eastern Trade winds that originate from the Sahara Desert. The mean annual rainfall ranges from 750 mm to 1100 mm. The rainfall pattern is so irregular and unreliable that there can be a long period without rainfall during the farming season. The district has only four humid months (June-September) throughout the year (GSS, 2014). The area is marked by high temperatures, ranging from 22.5^{0} C to 45^{0} C, in most parts of the year and low temperatures between December and January. The mean monthly maximum temperature is 33^{0} C whereas the daily highest is 35^{0} C.

The district lies within the savannah agro-ecological zone of Ghana. The climate of the area has given rise to Guinea Savannah grassland which is made up of short trees (shea, kapok, dawadawa, mango and baobab) luxuriant grasses and shrubs of varying heights (GSS, 2014; WWDA, 2012).

According to the 2010 Population and Housing Census, the total population of the Wa West District is 81,348 representing 11.6 percent of the total population of the region. The entire district is predominantly rural with rain-fed subsistence agriculture, more especially food crop cultivation, forming the largest single contributor to the domestic economy of the area. Over 90 percent of the workforce is engaged in the agricultural sector which accounts for 86.0 per cent of the district's economy (GSS, 2014; WWDA, 2012). Thus, farming, which is a male-dominated activity, is the main source of livelihood for the inhabitants, but communities close to the bank of the Black Volta engage in fishing (WWDA, 2012). The main staple crops that are cultivated on subsistence basis consist of guinea corn, yam, millet, sorghum, maize, cowpea, and groundnut. The district has comparative advantage in groundnuts and cowpea production. Some valuable economic tresses in the area include Dawadwa, kapok, Cashew, Mango, and Sheanuts (GSS, 2014; WWDA, 2012).

Most households in the district are also engaged in livestock production. Farmers integrate livestock production with crop cultivation. Livestock such as poultry (ducks, fowls, guinea fowls and turkeys), sheep and goats are commonly reared on free range system in the district. Pigs are also being reared by non-muslim households in the area (GSS, 2014; WWDA, 2012)

In addition to agriculture, other viable economic activities in the area include tourism (especially, Wechiau Community Hippo Sanctuary, the Lobi Architecture, Ga crocodile pond, a 300-year old Mosque, Chief Palaces and local grinding mills), rural commerce, industry and other social services.

Nkoranza North District

NND, with Busunya as its capital, is a transitional agro-ecological belt found in the Brong Ahafo Region of Ghana. It is located within latitudes 7^0 20' and 7^0 55' North, and longitude 1^0 10' and 1^0 55 West. The district is bordered by the Kintampo in the South and Pru Districts in the north, Atebubu Amantin District to the east, Nkoranza South District to the south and Techiman Municipality to the west. The zone has a total land area of 2,322km^2 which forms about 7.84% of total area of the entire Brong Ahafo Region (Boateng, 2015; NND A, 2016).

The district is found in the Voltain Sandstone Basin. The area is generally low-lying with height between 153m to 305m above sea level. There are two soil categories. One type developed in the savanna vegetation while the other is formed as forest ochrosols with some lithosols (GSS, 2014). Most soils are loamy and sandy loamy which are fairly rich in soil nutrients and can support the growth of trees like cashew and mango as well as variety of food crops such as maize, cassava, tomatoes, water melon, vegetables, yam, groundnuts, cocoyam and cowpea while cotton and tobacco are also cultivated in the north-eastern part of the district.

NND experiences wet semi-equatorial climatic conditions. Rainfall is between 800mm and 1200mm. The area has two rainy seasons. The main season occurs between April and June while the minor rainy season is between September and November. Dry spells do occur in some months. Mean annual temperature is about 26^0 C with the hottest months being February, March and April (Sienso, Asuming-Brempong & Amegashie, 2013).

The vegetation of the district has characteristics of both the savannah woodland of the north and the forest zone of southern Ghana. The northern and eastern parts are marked by savannah woodland re-growth in the form of shrubs and grasses whilst the southern portion has forest re-growth with trees such as silk cotton trees.

The population of NND is 65,895 with majority (81.5%) of the people residing in rural communities purposively to engage in agricultural related activities. Agriculture is the major economic activity in the district. About 70% of the economically active people are engaged in agriculture. Crops like maize, yam, cocoyam, beans, cassava, tomato, plantain, cowpea, sorghum, water melon and millet are mainly cultivated by farmers in NND (GSS, 2014; NND Assembly, 2016). Farmers in the area are also involved in animal production. Livestock such as rabbits, cattle, pigs, sheep, goats and grasscutters are reared in the area. The main poultry kept by farmers include local fowls, ducks, turkey, guinea fowls and pigeons (GSS, 2014; NND Assembly, 2016).

Other residents in the area also engage in small-scale manufacturing and agro-based processing activities such as blacksmithing, palm oil extraction, cassava processing soap-making, carpentry, welding, and dressmaking, sawmilling and bee-keeping. Tourism also provides revenue to the economy of NND. The district has rich tourist attraction sites more particularly the black and white Colobus Mona monkeys Sanctuary located at Boabeng-Fiema and the Pinihi Amovi Caves (NND Assembly, 2016).

Wassa East District

Wassa East District, with its capital at Daboase, is located on 5° 8′ 0″ N, and 1° 39′ 0″ W on the south-eastern fringe of Western Region. The district shares boundary with the Prestea Huni-Valley District in the west; Mpohor District in the east and Shama District in the south. It is also bordered on the northeast by Komenda-Edina-Eguafo-Abrem Municipal and Twifo Hemang Lower Denkyira District. WED also shares boundary in the southeast by Twifo Ati Morkwa District in the Central Region. The district has a total land area of about 1,651.992km^2 (GSS, 2014; WEDA, 2016).

WED is underlain by Cape Coast granite, Lower Birimian and Tarkwaian rock formations. These rock formations especially the Lower Birimian and Tarkwaian rock formations contain gold deposits in large quantities and traces of iron and Koalin. More than 50 percent of the soil type in the area is made up of the Cape Coast granitic soils. The district has low-lying and undulating topography. Most parts have highlands with heights ranging between 150 and 200 metres above sea level (Bourke et al., 2007; WEDA, 2016).

The district lies within the tropical climate zone with annual rainfall ranging from 1300 to 2000 mm. The district experiences its wet season between March and July while it dry period occurs from November to February. Although this rainfall pattern might be quite favourable for agriculture, global climate is changing and this might not be favourable to the present nature of agricultural activities in the area (WEDA, 2016).

The nature of the climate gives rise to tropical rainforest as the main vegetation type found in the district. The WED can boost of many forest reserves such as Subri River Forest Reserve, Ben West Block Forest Reserve, Ben East Forest Reserve and Pra Suhyen Forest Reserve (Bourke et al., 2007). The presence of the forest belt and forest reserves provides attractive tourist destinations to visitors and holiday makers.

WED has total population of 81,073. Out of this number, 74,834 (92.3%) residents live in rural communities. Agriculture (78.7%) constitutes the predominant economic activity for the people in this area and 95.1% of the households are engaged in crop farming. The major food crops produced include cassava, plantain, cocoyam, maize vegetables while cash crops like rubber, cocoa, coffee and oil palm are cultivated. Farmers mainly use traditional methods of farming practices (WEDA, 2016).

The existence of large deposits of gold, traces of iron and kaolin have also caused an upsurge in small-scale mining activities in areas such as Ateiku, Sekyere Heman, Sekyere Krobo and Nsadweso. Only 20 percent of the inhabitants undertake mining activities (GSS, 2014).

Rationale for choice of study areas

Agriculture is the predominant economic activity in the selected agro-ecological locations. Most people in these areas are involved in the production of food and cash crops as well as livestock. They depend on agriculture for food supply and income generation. Agriculture is the major contributor to the local GDP of these areas. Although majority of rural dwellers in these areas thrive on rain-fed agriculture, the sector tends to suffer from the impacts of climate change especially drought. Farmers in the Wa West District of Ghana are considered as the poorest people in the country but drought has worsened farming which is the main economic activity in this area (GSS, 2014).

Agyei-Antwi et al. (2012) acknowledged that besides Greater Accra and the Ashanti Regions which have the highest adaptive capacity, the remaining regions including Western and Brong Ahafo Regions of Ghana have medium adaptive capacity with Upper West, Upper East and Northern Regions being less resilient (lowest adaptive capacity). Furthermore, in the last decade, farming systems in the transition zone particularly the Nkoranza North District have been characterized by extended periods of drought (Egyir, Antwi, Ofori, Owusu & Ntiamoah-Baidu, 2015). Drought also hard hit Daboase and its communities which ran out of water supply in 2016. Similarly, they were concerns with residents' vulnerability to heat and drought (WED, 2016).

These study areas namely Wa West, Nkoranza North and Wassa East Districts were selected to serve as proxies for three agro-ecological locations (Savannah, Transitional and Forest agro-ecological zones respectively) because most farmers in these areas are exposed to droughts and are vulnerable as well as least capable of adapting to drought but most studies on farmers' vulnerability and adaptation are broadly based on climate change vulnerability (e.g. Apata, 2011; Fosu-Mensah et al., 2012; Obayelu et al., 2014; Ringer et al., 2014; Mabe et al., 2014; Shongwe & Masuku, 2014) and did not specifically focused on farmers' vulnerability and adaptation to drought in these areas. These communities also have diverse agro-practices and ecologies. Therefore, these agro-locations were chosen to help investigate whether there exists any variation in their vulnerability status and adaptation to drought.

Research philosophy

This study adopted the pragmatist epistemological perspective and specifically utilized both the positivist and interpretivist philosophical assumptions as the mode of inquiry. Pragmatism as a research philosophy holds that it is somewhat unrealistic to choose either positivism or interpretivism in the search for truth and meaning in life or resolving real-world challenges. This is particularly reasonable when the research topic and objectives do not clearly call for the use of either the positivist or interpretivist stance. In this philosophical quarrel, the adoption of a mixed method posture (quantitative and qualitative paradigms) is therefore recommended for researchers when addressing issues in real-life context (Creswell & Plano Clark, 2011).

The mixed method allows a researcher to nest one form of data within another larger data collection procedure in order to analyse different questions or levels of units in the study (Bell, 2010; Creswell & Plano Clark, 2011). Pragmatist orientation allowed for concurrent triangulation that helped offset the weaknesses that are inherent in either only the quantitative or qualitative technique. By concurrently merging both quantitative and qualitative data collection methods, the best of the single approaches was captured to present a comprehensive picture and provide a better understanding of the problem under investigation. Both forms of data were collected at the same time, analysed concurrently and then integrated for an overall interpretation. Hence, the qualitative dataset complemented the quantitative dataset.

Research design

The cross-sectional survey design was used to carry out the study. Surveys primarily aim at providing an accurate picture of situations and events being studied without any form of manipulation or control by the researcher. Cross-sectional design is the "most widely used type of research in the study of disaster vulnerability and resilience" (Zakour & Gillespie, 2013, p. 73). The design was employed to carry out this study because it has some practical advantages over longitudinal and experimental designs. Cross-sectional design helps researchers to capture large factual numeric and descriptive data from a large number of people that represents a wide target population on a one-shot basis. Hence, the design is less costly, more economical and efficient and allows researchers to measure variables with a high level of specificity (Bhattacherjee, 2012; Cohen, Manion & Morrison, 2011; Zakour & Gillespie, 2013). The design was used to conduct this study because it enabled the researcher to observe, describe and assess farmers' vulnerability and adaptation to drought within the selected agro-ecological locations of Ghana. Cross-sectional design also allowed for data collection from a large group of participants concerning farmers' vulnerability and adaptation to drought in the study areas.

Population

The target population for this survey comprised crop 1765 crop farmers in six selected farming communities within three agro-ecological locations and their distribution is shown in Table 2. These farming communities comprised Dorimon, Vieri (WWD), Pinihin, Sikaa (NND), Sekyere Aboaboso and Sekyere Abrodziwuram (WED).

Characteristically, these farmers cultivate crops such as maize, yam, groundnuts, millet, beans, cassava etc on small-scale subsistence basis. They also keep variety of livestock and poultry to supplement their farming and income activities. Generally, farming is a male-dominated activity in Ghana FAO (2012). Predominantly, the head of each household in these study areas is a male. However, in the absence of a male head, a female can act as the head of the household.

Sampling procedures

A total of 332 crop farmers were involved in this study. This was made up of a random sample of 326 farmers and six purposively selected lead farmers. Farming is a male-dominated economic activity in rural localities within the selected districts. However, some of the randomly selected individual farmers were females.

Each farming community had one lead farmer, apparently a male who had been recognized and titled on consensus based on farm size and level of crop and livestock productivity. They served as liaison officers between the community and MoFA officials at the regional and district levels. They also served as conveners of all meetings regarding farming activities in the communities. The roles played by the lead farmers made them well-informed on farming issues and hence, they served as key informants whose responses on drought vulnerability and adaptation reflect both rich personal opinion and the larger social pattern.

Out of the total population of 1765 household farmers, a random sample size of 326 participants was selected by using Yamane's (1967) formula for calculating sample size (n) based on a given population size as illustrated below:

$n=\frac{N}{1+N(e)^2}$ where N= population size and e= sampling error (.05)

$= 1765 / [1+1765 (.05)^2]$

= 326 farmers.

The distribution of population and sample size per study communities is shown in Table 2.

Table 2: Distribution of population and sample size per study communities

Agro-ecological zone	Community Name	Farmers per community	sampled farmers
Savannah zone	Dorimon	212	39
	Vieri	201	37
Transitional zone	Pinihin	315	58
	Sikaa	442	82
Forest zone	Sekyere Aboaboso	224	41
	Sekeyere Abroadziwuram	371	69
Total		1765	326

Source: Field survey (2017)

A multi-stage sampling which refers to the combination of two or more sampling methods was used to select the respondents. This sampling method was used because of the following reasons: firstly, it allowed for a combination of more sampling techniques in stages when conducting a study and secondly, it is appropriate when drawing samples from widely dispersed population (Bryman, 2004; Cohen et al., 2011).

At the first stage, the purposive sample technique was used to select the farming communities within the districts. Purposive sampling helped in making judgement about the selection of farming communities with typical and peculiar characteristics. Each selected community was a typical farming community (GSS, 2014) that was in a better position to provide the necessary information on farmers' vulnerability and adaptation to drought in each agro-ecological location. Comparatively, the selected farming communities in each agro-ecological location has more farming households and crop farmers.

In the second stage, the lottery method of the simple random method was used to select the 326 crop farmers to participate in the survey. The use of the simple random sampling technique ensured that each crop farmer in all the selected farming communities had equal and independent chance of being selected. The process of selection took into consideration the population proportion in the six farming communities. Two steps were followed to ensure that the selected random samples were proportionate to the total population of crop farmers in each farming community:

Step 1: determine the proportion of crop farmers in each farming community (ρ) by dividing the number of crop farmers in each farming community by the total population size: $\rho = n/N$

Step 2: determine the number of crop farmers to be selected from each farming community by multiplying ρ by the sample size to be used: $n = [(\text{sample size})\ (\rho)]$.

In using the lottery method, separate sampling frames for each of the selected farming communities were developed. The sampling frame was developed by the research team and this consisted of an alphabetical list of the names of all crop farmers in each selected farming community. The names listed in the sampling frame were substituted with numbered papers such that each piece of paper corresponded to a name of a farmer. To select the appropriate sample for a particular farming community, the numbered papers which represented names of crop farmers in that community were put in a container and mixed thoroughly. Thereafter, the numbered papers were randomly selected one by one without replacement from the container. The number that appeared on the selected paper was registered to correspond to a farmer's name. This process was continued until the required number of respondents in a farming community was reached. The process was repeatedly used in all the selected farming communities to select the 326 crop farmers

Osuala (2001) suggested that a purposive sample is best suited for carrying out interview schedules. In line with this, the purposive sampling technique was used to select the lead farmers for the key informant interview as well as the participants for the FDG. Thus, the six lead farmers were purposively selected. Moreover, with the assistance of the opinion leaders and a lead farmer in each farming community, groups of farmers who were best equipped were purposively selected to discuss and explore the issues under investigation.

Sources of data

Data was obtained from both primary and secondary sources. Structured questionnaire, key informant interview and focus group discussion were used to collect primary data from the selected farmers in the study areas. The primary data comprised socio-demographic characteristics of farmers, drought exposure, sensitivity, adaptive capacity, farmers' drought adaptation strategies and factors that constrain their adaptive capacity. Published books, journals and other documentary sources were consulted to obtain secondary literature. Monthly precipitation data of the selected study areas for the period of 1983-2014 were obtained from near-by Gmet stations.

Instruments

Household questionnaire, key informant interview schedules and focus group discussion guide were employed to collect data. Since structured questions with rating scales are limited by fixity of responses for respondents to select from a set of given options (Cohen et al., 2011), key informant interviews and focus group discussions were utilized to help overcome the limitations associated with the use of close-ended questionnaire. The items in the qualitative tools were open-ended questions to which the respondents could respond in their own expressions, opinions and terms.

Household questionnaire

The use of questionnaire allowed the farmers to complete it at their own convenient time, and also offered a greater assurance of anonymity with regard to whatever information that would be provided on their vulnerability and adaptation to drought. Most questions in the household questionnaire were close-ended. This is because using open-ended questions can generate irrelevant and redundant information and where such items are many, it may require much time before the respondents can think through to provide the right information that is being sought (Cohen, et al., 2011).

The variables used to develop the questionnaire were selected based on theoretical perspectives, views of agricultural experts as well as the available scholarly literature and previous studies on farmers' vulnerability and adaptation to climate change as well as drought. Based on this, indicators were developed to measure each component of vulnerability. The questionnaire was structured into six sections namely Section A, B, C, D, E and F (see Appendix B).

Section A which had 10 items sought data on farmers' socio-demographic profile such as name of community, gender, age, marital status, highest level of formal education, schooling years, years of farming experience, farm size, etc while Section B contained six items (Cronbach's alpha = .77) which measured farmers' exposure (drought frequency and severity) to drought along a 4-point rating scale ranging from 'low' (1); 'moderate' (2); 'high' (3) to 'Very High' (4).

Section C (i.e. item 18-45) contained drought sensitivity indicators namely social, economic and environmental indicators along a 4-point rating scale that ranges from 'Not at All (0) to 'High' (4). It had a high Cronbach's alpha= .86.

Moreover, Section D contained items that were designed to measure farmers' adaptive capacity based on their asset possession. These items had an overall Cronbach's alpha = .50 which is moderate but acceptable. To improve the reliability of this sub-scale, items with weak alpha values were deleted and not used in the final survey questionnaire (Field, 2009). Measures on farmers' drought adaptation strategies are contained in Section E of the questionnaire. This section had 15 adaptation strategies and participants were demanded to indicate either 'Adopted' (1) or 'Not Adopted' (1). These items yielded a high Cronbach's alpha = .72.

Finally, Section D elicited information on factors that constrain farmers' drought adaptation. This section contained nine measures structured along a 5-point Likert scale that ranges from 'strongly disagree' (1) to 'strongly agree' (5). Based on the results of similar empirical studies on constraints faced by farmers in adapting to drought, the respondents were presented with nine problems that served as constraints to their adaptation. The farmers were then asked to rate each constraint. It had a high Cronbach's alpha of .70.

Key informant interview

The key informant interview involved one-on-one conversation between the interviewer and the lead farmers. The lead farmers had the most accurate knowledge and information about the subject matter under investigation. Key informants played a pivotal role because they provide invaluable information that reflects both personal opinions and larger social patterns. They serve as proxies to the entire society (Fetterman, 2008; Parsons, 2008). The key informants were six purposively selected lead farmers who have real-life farming experience and are knowledgeable about the farming practices in the selected farming communities within the districts. A structured interview guide which contained 16 items was used to collect data from the key informants concerning drought impacts, their drought adaptation strategies as well as factors that constrain their drought adaptive capacity.

Focus group discussion

Focus group discussion is a data collection strategy used in qualitative research to explore attitudes, opinions or perceptions of participants towards an issue, product, service or programme through free and open discussion between members of a group and the researcher. In this technique, a researcher brings a sample of respondents together and asks them to respond to a structured sequence of open-ended questions (Dawson, 2007; Kumar, 2011). Kumar stated that it is a form of facilitated group discussion in which a researcher raises issues or asks questions that stimulate discussion among members of the group. It was used in this study as a qualitative research tool to explore farmers' experiences and knowledge on drought vulnerability and adaptation through free and open discussion between members of a group and the researcher. FDG was used because it has a high response rate and provides the possibility for clarification of emerging issues. This tool was also used because of its very usefulness of being able to yield detailed and rich information on a vast variety of issues as well as diverse opinions on different issues (Bell, 2010). Therefore, using FGD helped to gain more insight into the topic.

Opinions diverge on what constitutes the best size for FGD. According to Kumar (2011), the size of a focus group should neither be "too large nor too small as this can impede the extent and quality of the discussion" (p. 124). The optimal number for focus discussion group should be 6-8 people (Patton, 2002), 5-10 (Flick, 2010), 8-10 participants (Kumar, 2011) or 6-10 individuals (Bhttacharyya, 2012). With the assistance of the agricultural extension officer and/or other opinion leaders in the selected communities, eight farmers who were best equipped to discuss and explore the issues under investigation were purposively selected to constitute a focus group. One FDG was conducted in each selected farming community. Thus, six FDGs were conducted to carry out the study. A discussion protocol consisting of 11 pre-determined open-ended questions was used to carry out the FGDs. Open-form format of questions are advantageous because they allowed for free responses in the respondents' own words with regard to their vulnerability and adaptation to drought.

Pre-testing of instruments

Issues of reliability and validity are essential requirements for both quantitative and qualitative research. Pre-testing of instruments was carried out to help improve the reliability and validity of the data collection tools. Yin (2013) recommends a careful selecting of samples and appropriate instrumentation as measures to improve reliability and validity in qualitative data. These recommendations were strictly followed to achieve reliability and validity in the qualitative dimension of this study.

The validity of the household questionnaire, interview and FGD guides was determined and improved through the use of expert judgment from my supervisors and colleague researchers. In this regard, after developing the instruments, copies of the instruments were presented to my supervisors and other researchers for them to peruse and make the necessary comments as well as corrections. Moreover, these experts and other experienced researchers examined the content of the instruments to remove ambiguities, mechanical problems and irrelevant items from the devices. Face and content validity of the instruments was established by ensuring a logical link between the items in the instruments and the objectives of the study. This was done to ensure that the items in the instruments adequately and comprehensively covered all the objectives of the study. The corrections and suggestions from the experts were used to modify some items in the questionnaire, discussion protocol and interview guide.

Prior to the actual survey, the instruments were pre-tested in two farming communities namely, Asse and Ansapetu, in the savannah and forest agro-ecological zones respectively, by using a sample of 40 farmers. Twenty farmers were selected from each area. Similarity of sample characteristics was the key factor that informed the choice of these farming communities for the pre-test.

Pre-testing served as the pathway for validating the instruments through the discovery of possible misleading items, redundancies, inadequacies, ambiguities and problems associated with the instruments. It also helped to make the necessary corrections in the instruments before the actual data collection exercise. The pre-testing further helped check whether the items could provide the needed information in the actual study. It also paved way for me to gain feedback on the completeness and appropriateness of the items in the instruments. The completed questionnaires were collected, coded, and analysed with the aid of computer software known as SPSS (version 22.0). The Cronbach co-efficient alpha was calculated for the closed-ended items in the questionnaire.

Ethical considerations

The ethical dimensions were taken into consideration. A letter of introduction was sought from the Department of Geography and Regional Planning, UCC before visiting the study communities for data collection. Seeking official permission and using cover letter facilitated my entry into the farming communities. Before administering the questionnaire and conducting the FDGs as well as the key informant interviews, permission was sought from the chiefs, elders and opinion leaders of the various communities. To do this, meetings were held with the chiefs and opinion leaders of the concerned communities to provide them with my identity as postgraduate student from the UCC. The purpose of the research was then explained to them. After meeting with the chiefs and other opinion leaders, the lead farmers and in some instances, the assemblymen were implored to inform the entire community members about the purpose of the study. The informed consent of the participants was sought, their right to voluntarily participate in and withdraw from the exercise at any point in time was also guaranteed. The participants were also assured of anonymity, confidentiality, privacy, beneficence as well as non-maleficence. Thus, participants were assured that the exercise was purely academic and it would be of advantage to them and would not, in any form, harm them. Another issue that desired ethical consideration was the need for participants to be informed that tape recorder and video camera were to be used to record the proceedings of the interviews.

Data collection procedure

Two field assistants were recruited and trained to help in the data collection exercise. The survey was conducted within the period of May-July, 2017. During the period of the data collection exercise, the selected farmers were at home. Where there was the need, the survey instruments were administered to participants by using the local languages. This helped give a better understanding to some participants and hence, paved way for them to provide the needed information.

Administration of household questionnaire

During the actual data collection, copies of the questionnaires were personally hand-delivered to the respondents. Instructions were given to them concerning how to complete the questionnaire. The questionnaire was in filled in by some respondents who were literate while non-literate respondents were assisted by the researchers to fill the questionnaire. After giving guidelines on how to complete the instrument, each respondent was given 45 minutes or more to complete and return the filled questionnaire to me. The procedure was repeated in each household in the various communities until all the respondents were contacted.

Administration of key informant interview and focus group discussion

Firstly, a good rapport was established and maintained with the participants. This helped to create a clear, polite, non-threatening and personable atmosphere to carry out the individual and group interviews. The interviewees were given the mandate to decide where and when the interview was to be conducted. Before conducting the FDGs, consultations were held with the members of the group to finalize the process of the discussion. This included fixing of time and venue. Whenever it was time for an actual interview or discussion, the research team firstly introduced themselves and the participants were also asked to introduce themselves either by using their first names or pseudonyms if they wished. This was followed by a statement on the general purpose of the study to the discussants. The expected duration, the ground rules of the engagement, the need to record their responses, and the need for cooperation were also explained to the participants. The discussants were also assured of anonymity, confidentially, privacy and the right to drop out if the need arises. After this, questions were posed to members of the group to freely discuss in turns. Thus, when a question is raised, an individual participant was called upon to respond. This process enabled the group to extensively discuss the issues to arrive at logical conclusions. Proceedings from the discussions were recorded by using two different audio recorders. The digital recording was backed by handwritten notes. This process was repeatedly used to collect data from farmers in the selected farming communities. In all, six different FGDs and six key informant interviews were held. After the discussion, the research team expressed deep appreciation and gratitude to participants for their time spent and contributions made towards the success of the discussion.

Data processing and analysis

In line with the research philosophy and the type of data that was generated, both qualitative and quantitative data analysis techniques were used. Below is a description of how the data processing and analysis was carried out.

Transcription is considered as the first crucial step in the process of analysing qualitative data. After the transcription, the transcripts were carefully read. The tape records were listened to several times so as to get a complete sense of the data.

In analysing the qualitative data, the logical induction approach was followed to organise, account for and interpret the data. All the transcribed data was coded by following the guidelines prescribed by Miles and Huberman (cited in Cohen et al., 2011). In doing this, patterns from the data were identified and the data was sorted and then organised into notable patterns, categories and themes for thick descriptions based on the various research objectives. This helped make sense of the data in terms of farmers' vulnerability and adaptation to drought as well as their adaptive constraints.

Multiple tools were employed to analyse the quantitative data. This comprised the use of Standardized Precipitation Index, descriptive statistics (frequencies, percentages and composite indexing) and inferential statistics (Kruskal-Wallis test, Pearson Chi-Square statistics, Logit regression).

Standardized Precipitation Index (SPI)

The monthly precipitation data from 1983-2014 was used to analyse the drought index and hence, assess the spatial and temporal variability of meteorological drought across the three agro-ecological zones from 1983-2014. The analysis of drought characteristics was done by using the Standardized Precipitation Index (SPI) proposed by McKee, Doesken and Kleist (1993). These American scientists developed the SPI based on the understanding that precipitation deficit impacts differently on underground water, reservoir storage system, soil moisture, snowpack as well as streamflow conditions (WMO, 2012).

The SPI transforms a series of precipitation dataset into series of anomalies usually expressed as z-scores and summates the precipitation deficits of different time scales (Lorenzo-Lacruz & Moran-Tejeda, 2016). It expresses actual rainfall data as log normalized values indicating the departure from rainfall probability functions.

Moreover, the filled questionnaires were collected and edited in order to remove those that were not well and fully answered. The responses for items with options or Likert-type scale were coded and organised for further analysis. After the coding exercise, the data was fed into a computer-based software known as Statistical Package for Social Sciences (SPSS Version 22.0) and finally exported into STATA 14 and Microsoft Excel (2016) for further processing and analysis. The inferential statistics were tested at 95% confidence level (2-tailed).

Descriptive statistics (frequencies, percentages, means and standard deviations) and index ranking (Weighted Average Index [WAI]) were used to analyse the data on farmers' rating of the socio-economic and environmental impacts of drought. Farmers' responses for drought impacts were rated by using a four-point scale with the scoring order 3, 2, 1 and 0 as 'high', 'moderate', 'low' and 'not at all' respectively. The formula for the WAI analysis is as follows:

$\frac{\Sigma F_i W_i}{\Sigma F_i}$ where *F* = frequency; *W* = weight of each scale; *i* = weight; (Adesoji & Famuyiwa, 2010; Devkota, Cockfield & Maraseni, 2014; Falola & Achem, 2017; Uddin et al., 2014; Ndamani & Watanabe, 2016).

Furthermore, index values were computed for each of the three components of vulnerability. Finally, the Drought Vulnerability Index (DVI) for each zone was calculated by using the formula:

DVI = Exposure [E] + Sensitivity [S] – Adaptive Capacity [AC].

The drought vulnerability for each zone is a composite indicator quantified by the weighted aggregation of exposure and sensitivity minus adaptive capacity. This is because adaptive capacity has inverse functional relationship with vulnerability. The data did not satisfy the assumptions of normality and homogeneity of variance. Therefore, Kruskal-Wallis test, a non-parametric alternative of test of Analysis of Variance (ANOVA) was employed to further investigate whether there is any statistically significant variation between the three agro-ecological locations and their levels of drought vulnerability.

Pearson Chi-square test of significance was first employed to analyse the data on farmers' adaptation strategies across the three agro-ecological zones in Ghana. This helped to compare farmers' adaptation practices across the three selected agro-ecological zones. As previously indicated, each adaptation strategy was a dummy variable coded as 0 (implying non-adoption) and 1 (implying adoption). The Phi and Crammer's V were generated as measures of contingency co-efficient to explore the strength of the association between the agro-ecological zones and farmers' adaptation.

Furthermore, binary logistic regression model (using Maximum Likelihood Estimation) was used to investigate the predictive validity of farmers' socio-demographic variables on their choice of the individual adaptation measures. Table 3 presents a description of explanatory variables used in model.

Table 3: Description of explanatory variables used in model

Variable	Description	Apriori sign
Agro-ecological zone	The zone in which the farming community is located (coded as 0 = Forest, 1= Transition and 2 = Savannah	+
Gender	This captures the gender of the farmer (dummied as 1= Male, 0= Female)	+
Marital status	This refers the participants' status of marriage either customarily or legally (coded as 0= single, 1 = married, 2= Divorced and 3 = Separated	+
Years of schooling	This represents the number of years spent to attain a given level of formal education (measured as continuous variable)	+
Household size	The number of people in a headed-house who eat from a common cooking pot (measured as a a continuous variable)	+/-
Farming experience	This means the years that a participant has engaged in farming activities (measured as a continuous variable)	+
Farm size	This means the size of a farm in acres (measured as continuous variable)	+/-
Access to credit facilities	This deals with whether a farmer own or can get credit in the form of funds (1= Yes, 0 = No)	+
Membership of association	This refers to belongingness to or being a member of farming-related social club/group (1= Yes, 0 = No)	+
Access to extension service	This refers to farmers' personal contact with extension officers (1= Yes, 0 = No)	+

Descriptive statistics (frequencies and percentages) were computed for each constraint to drought adaptation. The researcher finally adopted the Problem Confrontation Index (PCI) as used in previous studies on problems confronting farmers (Alam & Rashid, 2010; Rahman, Yamao & Alam, 2007; Hossain & Miah, 2011; Roy, Farouque & Rahman, 2013; Uddin et al., 2014, etc.) to compute an index for each problem by using the index formula:

$PCI = [5(P_{SA}) + 4(P_A) + 3(P_N) + 2(P_D) + (P_{SD})]$

Where,

PCI = Problem Confrontation Index

P_{SD} = Frequency of farmers who rated the problem as strongly disagree

P_D = Frequency of farmers who rated the problem as disagree

P_N = Frequency of farmers who rated the problem as not sure

P_A= Frequency of farmers who rated the problem as agree

P_{SA} = Frequency of farmers who rated the problem as strongly agree

The various indices were used to rank farmers' problem confrontation in drought adaptation. The possible value of each problem confrontation in farmers' adaptation to drought could range from 1 to 1,630. A minimum index of 326 indicates that all the farmers (N=326) strongly disagree with a particular problem while a maximum index of 1,630 indicates that all respondents strongly agree with a problem confrontation.

Limitations

In conducting a study of this nature, certain limiting factors were encountered that might affect the reliability and validity of the results. A crucial limiting factor was the inability to employ multiple techniques to collect data from the respondents. For instance, there would have been the need to employ rural participatory approaches such as on-farm visits or transect walks to the farms in the various communities in order to really ascertain farmers' adaptations strategies rather than eliciting their views on how they adapt to drought which might differ from the situation on the grounds. Farmers' views might mask the reality with respect to their drought adaptation.

The use of surveys can impair the internal validity of this research. The measures in this study made use of a Likert-type scale. Therefore, there is the propensity for respondents to give consistently high or low rating (Thomas, 2007; Bray & Williams, 2017). Similarly, Bhattacherjee (2012) argues that cross-sectional surveys, particularly, may be liable to respondent biases where respondents may offer "socially desirable" responses rather than the accurate responses.

Vulnerability is a complex, difficult qualitative concept that is measured and calculated quantitatively by using either secondary data or personal judgment. Due to unavailability of reliable secondary dataset on drought sensitivity, exposure and farmers' adaptive capacity, the method of calculating the vulnerability index was based on the farmers' subjective assessment which might mask their true vulnerability status. However, vulnerability is not static. Using data from farmers' personal assessment of their vulnerability status catered for the dynamism of vulnerability (Tesso, Emana & Ketema, 2012).

Finally, the results lack generalizability to the entire agro-ecological zones in Ghana. This is because the selected farming communities and the respective sample sizes are not representative of farmers' population in each selected agro-ecological zone.

Some measures were taken to help overcome these challenges and hence, increase the reliability and validity of the results. The biases were reduced through careful instrumentation. Firstly, the indicators used to develop the instruments were carefully selected to reflect the three components of drought vulnerability. Secondly, through the use of a mixed research strategy, the researcher was able to triangulate and improve the validity of the findings obtained from the samples (Yin, 2013).

The respondents were also provided with clear instructions and appropriate interpretations on choice of the scales used in the questionnaire. The participants were admonished to provide trustworthy responses. They were also assured of confidentiality and anonymity. Finally, the survey was conducted face-to-face at the individual's home, and this gave the "the researcher greater insight into the respondents' true opinions and beliefs" and to give more time for filling in the questionnaire as well as asking questions for clarification (Jackson, 2011, p. 93).

Chapter summary

Chapter Three presents the research methods followed to carry out the study. The first part discusses the research philosophy and design followed to examine farmers' vulnerability and adaptation to drought in the three agro-ecological areas. The second part is devoted to a description of the research paradigm and design, population, sample and sampling procedures, sources of data, instruments, issues of reliability and validity, data collection procedures, ethical considerations as well as data processing and analysis.

CHAPTER FOUR

SOCIO-DEMOGRAPHIC PROFILE OF RESPONDENTS

Introduction

This chapter discusses the socio-demographic profile of the 326 crop farmers in the three agro-ecological locations that participated in the study. The socio-demographic characteristics that were examined comprise participants' gender, age, marital status, level of formal education, farming experience, farm size, household size, size of landholding as well as number of dependents. The results in Figure 5 show that out of the 326 participants, majority of 205 (62.9%) farmers were males whereas 121 participants representing 37.1% were females. This suggests that most of the farmers who participated in the study were males. Figure 5 illustrates the gender of the respondents across the three agro-ecological locations.

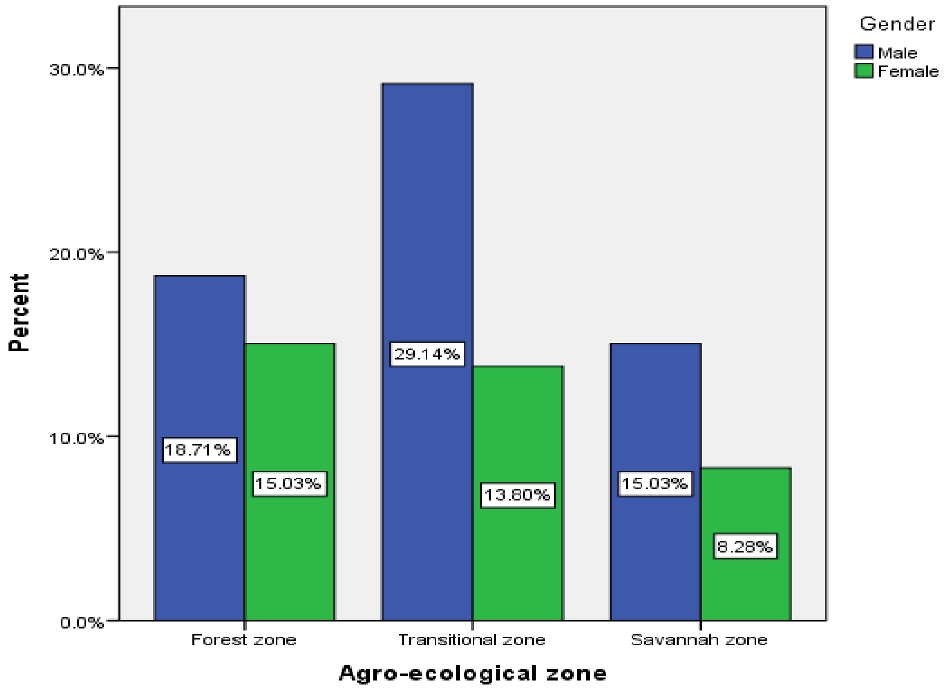

Figure 5: Sex composition of participants across agro-ecological locations

Source: Field survey (2017)

From Figure 5, there was a higher proportion of male farmers (29.14%) in the Transitional zone compared to the other agro-ecological locations. The results further indicate that the proportion of female farmers in the Forest zone (15.03%) was the same as the proportion of male farmers (15.03%) in the Savannah zone. The percentage of female farmers (8.26%) was comparatively quite less in the Savannah zone. Overall, farming is a male-dominated economic activity across the three agro-ecological zones. This finding is consistent with gender profile in farming in Ghana. According to FAO (2012), there is gender inequality in rural employment in Ghana. Most rural women in Ghana, particularly in the survey communities, rather engage in non-agricultural activities especially commercial ventures for their livelihood. This is in line with FAO (2012) report that rural women highly engage in marketing (wholesale and retail) and tourism, and cottage manufacturing activities.

Furthermore, data on participants' marital status was measured categorically. The results obtained with respect to this variable are presented in Table 4.

Table 4: Farmers' marital status across agro-ecological locations

Agro-location	Marital status								
	Single (n=58)		Married (n=222)		Divorced (n=17)		Separated (n=29)		N= 326
	Freq	%	Freq	%	Freq	%	Freq	%	
Forest	17	15.5	76	69.1	7	6.4	10	9.1	110
Transition	35	25.0	81	57.9	9	6.4	15	10.7	140
Savannah	6	7.9	65	85.5	1	1.3	4	5.3	76

Source: Field survey (2017)

The results in Table 4 show that out of the 326 crop farmers, majority of 222 farmers, representing 68.1%, were married whereas 58 (17.8%) farmers were single. The results indicate that most of the participants in the study are married farmers. This means that farmers in the selected agro-ecological locations do not have many cases of divorce. Indeed, the couples usually live together to complement each other in their livelihood activities.

Furthermore, it is obvious from the results presented in Table 4 that out of the 110 farmers in the Forest agro-ecological location who participated in the study, 76 (69.1%) were married. Cases of marital divorce and separation in the Forest zone were 6.4% and 9.1% respectively as shown in Table 4.

The marital status of farmers in the Transitional zone bears resemblance to that of farmers' marital status in the Forest zone. From Table 4, the result indicates that 81 (57.9%) out of the 140 farmers in the Transitional zone who participated in the study were married farmers. Only nine (6.4%) and 15 (10.7%) farmers in the Transitional zone were divorced and separated respectively.

Out of the 76 farmers from the two selected farming communities within the Savannah agro-ecological zone that participated in the study, the results as presented in Table 4 indicate that 85.5% were married while only one farmer (1.3%) had a divorce case in his/her marriage. There were four cases (5.3%) of marital separation in the Savannah zone. This means that most farmers in the Savannah zone are married couples. Generally, the study reveals that most farmers who participated in the study were married. Indeed, rural farmers mostly depend on their immediate families for source of labour.

Similarly, a farmer who marries can get additional support from the opposite sex to augment his/her agricultural activities.

Farmers' level of formal education

The participants were also asked to indicate their highest level of formal educational attainment. Figure 5 presents the results on farmers' level of formal education across the three agro-ecological locations.

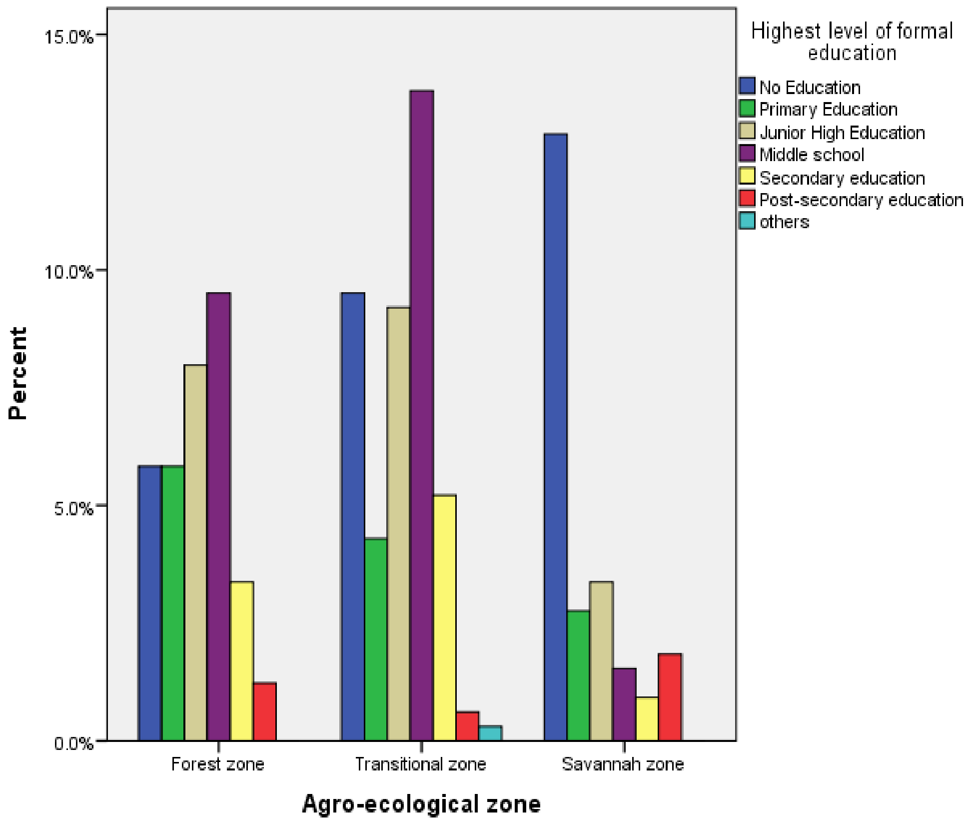

Figure 6: Farmers' level of education across agro-ecological locations

Source: Field survey (2017)

From the results in Figure 6, the proportion of farmers in the Forest agro-ecological location who obtained middle school education (9.51%.) is less than the proportion of farmers in Transitional agro-ecological location with middle school education (13.80%). Moreover, there was a smaller number of farmers in the Savannah zone who attained middle school education. This implies that most farmers in the Forest and Transitional zones had completed middle school compared to their farming counterparts in the Savannah zone where majority (12.88%) had no education. However, most farmers in the Savannah zone obtained post-secondary education (1.84%) compared to the proportion of post-secondary school holders of 1.23% and 0.31% farmers in the Forest and Savannah agro-ecological locations respectively who attained post-secondary education. Only one farmer in the Transitional zone indicated that he obtained a Diploma in Book Keeping.

Overall, most of the farmers have varying degrees of educational qualifications. The educational background of the selected farmers presupposes that these farmers would have knowledge and understanding of climatic events as well as climate change adaptation. Ceteris paribus, farmers with formal education will be more resilient to drought than farmers without formal education. As indicated by Apata (2011), education among farmers can promote climate change adaptation. Similarly, other empirical evidence from a study conducted by Abdul-Razak and Kruse (2017) indicated that farmers with formal education had high adaptive capacity while farmers without formal education had low adaptive capacity to cope with climate change and variabilities.

Furthermore, the participants were asked to indicate their age, years of schooling, farming experience, farm size, landholding, household size and dependents. The descriptive statistics on these continuous numeric variables are presented in Table 5.

Table 5: Participants' age, years of schooling, farming experience, farm size, landholding, household size and dependents

Continuous variable	N	Min	Max	Mean	SD
Age (in years)	326	18.00	87.00	43.99	14.12
Years of schooling	326	0.00	22.00	6.89	4.79
Farming experience (in years)	326	1.00	76.00	18.96	13.45
Farm size (in acres)	326	1.00	55.00	6.83	6.80
Landholding size (in acres)	326	2.00	250.00	13.77	16.66
Household size	326	1.00	25.00	6.37	3.56
Number of dependents	326	.00	10.00	2.83	2.08

Source: Field survey (2017)

From the summary statistics of the 326 crop farmers presented in Table 5, the least age of the farmers was 18 (Min= 18) while the highest age was 87 (Max =87). On the average, the farmers were 43.99 years old (Mean = 43.99, SD = 14.12). Similarly, the result as shown in Table 5 is indicative that the participants have been farming for almost 19 years (Mean =18.96, SD = 13.45). Thus, the average farming experience is 18.96 years while the minimum and maximum years of farming experience are one year and 76 years respectively. This shows that the farmers in the selected areas have been engaged in the agricultural sector for quite a long time. With their age and farming experience, the selected farmers could offer rich information on their drought exposure, sensitivity and adaptation. This confirms other research which illustrated that farmers' experience have influence on their level of knowledge on climate change adaptation and risk management (Apata, 2011; Gbetibouo, 2009; Montle & Teweldemedhin, 2014). Thus, the age profile of the farmers implies that they were mature enough and could provide valuable information in respect of their drought vulnerability and adaptation.

It is also clear from the results presented in Table 5 that the selected farmers had an average of 6.83 acres (Mean = 6.83, SD = 6.80). Moreover, farmers had 1.0 acre and 55.0 acres as minimum and maximum farm size respectively. It was revealed that most of the farmers who had large farms cultivated both cash and food crops. For instance, most farmers in the Forest zone planted vast acres of cocoa whereas some farmers in the Transitional zone cultivated cashew plants on large scale. Food crops such as maize, yams, beans and groundnuts were cultivated by farmers in the Savannah zone on small scale. The researcher's interaction through qualitative techniques revealed that most farmers have decreased their farm sizes or abandoned farming entirely in order to reduce the risk of income and crop loss due to poor rainfalls. In a focus group discussion, a male farmer in the Savannah zone remarked that:

> *I used to cultivate maize on three acres of land. But I was not getting any positive crop yield owing to scanty and unreliable rains. Drought had caused me to stop farming so that I would rather use my money to buy food stuff. It is even this year that I tried and cultivated only one acre which is divided into three plots so that I can plant different crops* (FGD, Male participant).

From Table 5, the results show that farmers' landholding ranged from at least 2.0 acres to a maximum of 250 acres. Farmers in the selected study areas had a landholding of 13.77 acres on the average. This implies that access to land to undertake agricultural activities may not constitute a problem to the rural farmers.

The minimum and maximum household size were one and 25 persons respectively. The average household size was found to be six (Mean = 6.37, SD= 3.56). Moreover, the number of dependents in households ranged from zero to a maximum of 10. Households had about three dependents on the average (Mean = 2.83, SD = 2.08). These demographic features imply that household sizes are relatively quite small with small number of dependents. Small family size implies less labour endowment for farmers. This relatively small family size might even account for the rural farmers' inability to put up large farms. In another dimension, drought impacts on farming could have reduced fertility rates among distressed farmers and subsequently decreased family sizes in the farming communities. For instance, during a FGD, a female discussant alluded that:

> *Drought affects every aspect of our family life. Sometimes, we brood over how to earn our daily bread to the neglect of having marital sex. Even our husbands become stressful during drought episodes and have less or no desire for sex* (Female discussant, Savannah Zone).

Chapter summary

This chapter discusses the socio-demographic profile of the 326 crop farmers in the three agro-ecological locations that participated in the study. The socio-demographic characteristics that were examined comprise participants' gender, age, marital status, level of formal education, farming experience, farm size, household size, size of landholding as well as number of dependents.

CHAPTER FIVE

SPATIO-TEMPORAL VARIATION IN DROUGHT IN THREE AGRO-ECOLOGICAL LOCATIONS OF GHANA: A COMPARATIVE ANALYSIS

Introduction

Precipitation amounts are not uniformly distributed over time and within the same location. Globally, areas are affected by more droughts and excessive rains. Easterling et al. (2000) reports that many areas of the globe have experienced statistically significant increase in rainfall amounts. Similarly, NASA (2007) assembled and analysed a 27-year-long global rainfall record from satellite and ground-based instruments. The analysis showed a global rise in rainfall trend and that, nearly two-thirds of all rainfalls occurred in the tropics. The results further showed that tropical areas have experienced 5 per cent rise in rainfall amounts, with 0.5mm per day per decade. However, the increase in tropical rains is concentrated over tropical oceans, with a slight decline over tropical lands. The scientists found that the rainiest year occurred between 1979 and 2005. 2005 was the wettest year, followed by 2004, 1998, 2003 and 2002, respectively (NASA, 2007). Conversely, other reports indicate that there are declining trends and anomalies of annual trends in precipitation variability throughout the globe (IPCC, 2007; Sun, Roderick & Farquhar 2012).

Most parts of Africa have well-defined wet and dry seasons that are mainly determined by the ITCZ and the West African Monsoon. African sub-regions, particularly West Africa, have experienced a remarkable spatial and temporal variability in rainfall amount and pattern. This pattern of rainfall variability is associated with the timing, variation and intensity of the ITCZ and the West African Monsoon. The location and intensity of the ITCZ and the occurrence of the monsoon winds collectively account for the variation and timing of climate patterns in Africa (Stanturf et al., 2011). Different rainfall patterns are associated with various climatic zones which emerge as a result of the north-south drift of the ITCZ (Akpoti, 2015; GMeT, 1998–2016).

Climatic pattern varies across the ecological zones of Ghana. Similarly, the effect of climate change is different across the zones of Ghana. Generally, northern Ghana has savannah zone and this region experiences only one rainy season. Rainfall is low and decreasing while temperature has been increasing in the last several decades. The combined effect of these factors makes northern Ghana the most vulnerable region to the adverse impacts of climate change (World Bank, 2010; Stanturf, et al., 2011).

Precipitation appears to be gradually declining in most parts of Ghana. There is delay in the onset of wet seasons and reduction in the number of days for wet periods (Lacombe, McCartney & Forkuor, 2012). This has caused seasonal droughts and dry spells in various parts of Ghana over the years. Similar studies in Ghana by Gyau-Boakye and Tumbulto (2000) and Owusu (2009) have reported overall downward trend in annual rainfall totals. Moreover, Owusu and Waylen's (2009) analysis of rainfall data based on all the four agro-ecological zones of Ghana from 1951 to 2000 (divided into two 20-year periods 1951–1970 and 1981–2000) showed that mean annual rainfall totals in all the stations within all the four agro-ecological zones observed downward trends from the initial period to the latter except at Kete-Krachi in Zone C (Transitional zone). Other rainfall analyses showed that annual rainfall in all the agro-ecological zones of Ghana is decreasing. Generally, rainfall has declined from 1981-2010, with a shift in its pattern (Logah, et al., 2014). The downward trend occurred between 1960-2008, with a mean decline of 2.3 mm per month (2.4%) per decade (Nkrumah et al., 2014). However, a study by Logah, Ofori and Kankam-Yeboah (2014) which analysed rainfall data from 77 stations for the 1981-2010 period has shown that a slight general increment in the trends of the mean, minimum and maximum annual rainfall occurred in the country. They found that Western Region continues to have high rainfall amount while the savannah zone particularly Upper East Region receives less rains. Furthermore, Baidu et al. (2017) conducted a wavelet analysis using a time series rainfall data from 1901–2010 across Ghana. The results showed a high annual rainfall totals ranging from 900–1900 mm throughout Ghana with mean annual rainfall totals in the country exhibit a strong spatial decline from the South to North. Baidu et al. (2017) also observed a below normal rainfall in almost all the agro-ecological zones between 1901–1905, 1908–1920, and 1980–2010; very high totals between 1500–1900mm in the south-west, and low totals (900–1200 mm) in the savannah and east coast of Ghana. Results of these studies confirm the assertion that rainfall pattern in Ghana exhibits seasonal character and high inter-annual variability on inter-decadal timescales (Amikuzuno & Donkoh, 2012). These conflicting reports affirm the perspective that there are anomalies in rainfall variability in the country.

Rainfall anomalies lead to drought in various parts of Ghana. However, various models and analyses of rainfall patterns failed to examine the spatio-temporal pattern of drought in the country. There is therefore the need to analyse the spatio-temporal variation in drought since this can shed light on the nature and severity of drought across space and time particularly in the selected agro-ecological locations of Ghana.

Methods

The spatio-temporal variation in drought for the period 1983-2014 was examined using historical rainfall data for the same climatological year. The data was obtained from GMet stations. The data consisted of monthly precipitation data for Daboase, Busunya and Wechaiu for the Forest, Transitional and Savannah agro-ecological zones respectively.

The monthly precipitation data from 1983-2014 was used to analyse the drought index and hence, assess the spatial and temporal variability of meteorological drought across the three agro-ecological zones from 1983-2014. The analysis of drought characteristics was done by using the Standardized Precipitation Index (SPI) proposed by McKee, Doesken and Kleist (1993). These American scientists developed the SPI based on the understanding that precipitation deficit impacts differently on underground water, reservoir storage system, soil moisture, snowpack as well as streamflow conditions (WMO, 2012).

The SPI transforms a series of precipitation dataset into series of anomalies usually expressed as z-scores and summates the precipitation deficits at different time scales (Lorenzo-Lacruz & Moran-Tejeda, 2016). It expresses actual rainfall data as log-normalized values indicating the departure from rainfall probability functions. The calculated values for SPI are usually standardized. Positive values of SPI indicate more than median precipitation while negative SPI indicates less than median precipitation (Edwards & McKee, 1997).

SPI is a more suitable index that can be used to identify meteorological drought and non-drought years. It is the most widely used and considered by the World Meteorological Organisation as a universally accepted reference index for drought analysis (particularly drought spatial and temporal consistency), monitoring and impact assessment as well as drought management and decision-making (WMO, 2012). The SPI has some practical advantages over other drought indices. It is a very powerful and flexible tool for analysing both wet and dry cycles and it requires at least 20-30 years of monthly precipitation values as the only input parameter. SPI is suitable for comparing departure from normal precipitation in various locations with different climates. Although it is not an appropriate tool for climate change analysis because it does not require temperature and other variables as input parameters (WMO, 2012), the SPI is a suitable tool for quantifying the severity of drought at different timescales (Di Lena, Vergni, Antenucci, Todisco, Mannocchi, 2014; Hayes, Svoboda, Wall, Widhalm 2011; Lorenzo-Lacruz & Moran-Tejeda, 2016). According to McKee et al. (1993), SPI value of -1.0 or less depicts drought while positive values indicate wet periods. It demands less complex computation and it is easier to understand compared to the Palmer Drought Severity Index (Zarga, Sadiq, Naser & Khan, 2011). Moreover, the SPI provides a signal of early warning of drought and helps to assess the severity of drought at variable timescales.

The inclusion of multiple timescales in SPI allows the results to reflect similar conditions as in other drought indices. This allows for flexibility in the evaluation of precipitation deficits. These variable time scales also give a reflection of drought impacts on different water resources. Short-medium term

(3-month, and 6-month) time scales reflect meteorological and agricultural drought conditions while long-term (9- month and 12 consecutive month) time scales relate to impacts of precipitation anomalies on streamflow, reservoirs, and groundwater (hydrological drought) (WMO, 2012). According to Zargar et al. (2011), SPI < –1.5 is a good indication that substantial drought impacts can occur in the agricultural and possibly other sectors (McKee et al., 1993; WMO, 2012).

SPI value of -1.0 or less depicts drought while positive values (+1 and more) indicate wet period. The original convention was that SPI values of 2.0 or more = Extremely wet; 1.5 to 1.99 = severely wet; 1.0 to 1.49 = moderately wet; -.99 to .99 = near normal while -1.0 to -1.49 = moderate drought; -1.5 to -1.99 = severe drought; -2 and less = extreme drought (McKee et al., 1993).

Results and discussion

This section discusses the results of SPI which shows the pattern of drought for 1983-2014 climatological period. The results are presented and discussed based on the three selected agro-ecological zones. The SPI for each zone is visualized graphically representing 3-month, 6-month, 9- month and 12 consecutive month time scales.

Drought and rainfall pattern in Daboase

The SPI time scale graphs in Figure 7 show the variations in drought and rainfall pattern in Daboase. As previously indicated, the analysis of drought and rainfall pattern is based on 3-month, 6-month, 9- month and 12 consecutive month time scales.

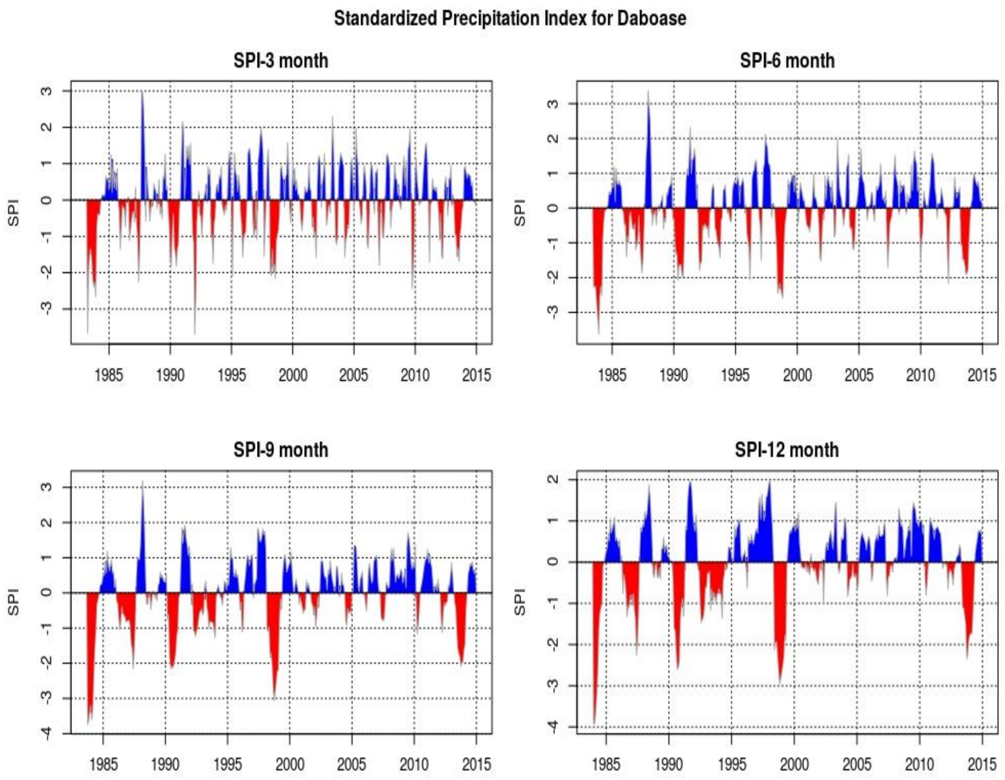

Figure 7: Drought and rainfall pattern in Daboase

The trend analysis in the 1-3-6 month short-medium time scale shows that frequent drought conditions have been interspersed with moisture conditions throughout the 1983-2014 period in Daboase. Meteorological drought occurred more frequently in the 1-3 month short-term scale throughout the 1983-2014 period. The SPI values for Daboase are in line with Logah et al. (2014) acknowledgement that portions of the forest belt received less rainfall between 1981 and 2010. However, in the 1-12 long-term time scale, it is clear that incidence of drought was sporadic in Daboase. This means that inter-annual moments of drought are rare in this area.

From Figure 7, the analysis shows that prior to 1985, the drought index (SPI = -2.0 and less) indicates extremely dry conditions in the area. This implies that there was extreme drought condition prior to the 1985 climatological year in Daboase. This confirms previous information on drought analysis which indicated that incidence of drought was quite a normal climatic event in Ghana with the 1983 drought being the worst and severest (Laube et al., 2008; Van der Geest, 2004). The rainfall anomalies around this period could affect soil moisture and the agricultural sector of the economy and increase farmers' vulnerability status to drought. 1985 was marked by moderately wet conditions (SPI =1.0). Moreover, in the middle of 1985-1990, there were periods that were extremely wet as shown by SPI= +2.0 which shortly followed an extreme drought condition (SPI = -2.0). The non-drought period in Daboase occurred in 1990. This could favour agricultural production in the study area.

The time series graphs for drought and precipitation pattern in Daboase further indicate that both extreme and severe droughts occurred much more between 1990-1995 period compared to moments of wet conditions. In the short-medium term analysis (1-6 months), two cases of severe drought conditions (SPI = -1.5) did occur between 1990-1995 period while in the long-term time scale (1-12 month), dry conditions were quite extreme (SPI=-2.0) around 1991. Mid-way between 1990-1995 period was punctuated by extremely wet conditions and this could increase farming activities before and after the dry conditions between 1990-1995 period to lessen farmers' vulnerability. Similarly, the area also recorded high rainfall between 1995-2000. Although there was a severe drought just before 2000, it must be emphasized that the 1995-2000 climatological period marked the highest inter-annual rainfall accumulation and Daboase was therefore extremely wet around this period (SPI = +2.0). The year 2000 was a non-drought period in Daboase. After the extreme wet conditions mid-way between 1995-2000, there was a period of extreme drought (SPI = -2.0 and less) which was less than the 1983-1985 drought.

The trend analysis for Daboase in Figure 7 shows that the rainfall pattern approximates a near normal condition for the period of 2000-2010 (SPI= -.99 to .99) with more periods of wet conditions than dry periods in the long-term time scale (1-12 month). It must be pointed out that between 2000-2010, Daboase also recorded less rainfall anomalies and hence, droughts did not occur. This 10-year period marks the extended 'non-drought years' in Daboase. This pattern continued up to 2012. However, the SPI values in Figure 7 imply that moments of extreme drought occurred before 2014 (SPI =-2.0). The degree of severity of the drought around this period is less than the severe drought which occurred between 1983-1985 and 1995-2000 and this could negatively affect agricultural activities and other water resources in Daboase zone.

Drought and rainfall pattern in Busunya

SPI was also used to analyse the trend of drought and precipitation for Busunya which is located in the Transitional zone of Ghana. The various SPI time scale graphs are shown in Figure 8.

Standardized Precipitation Index for Busunya

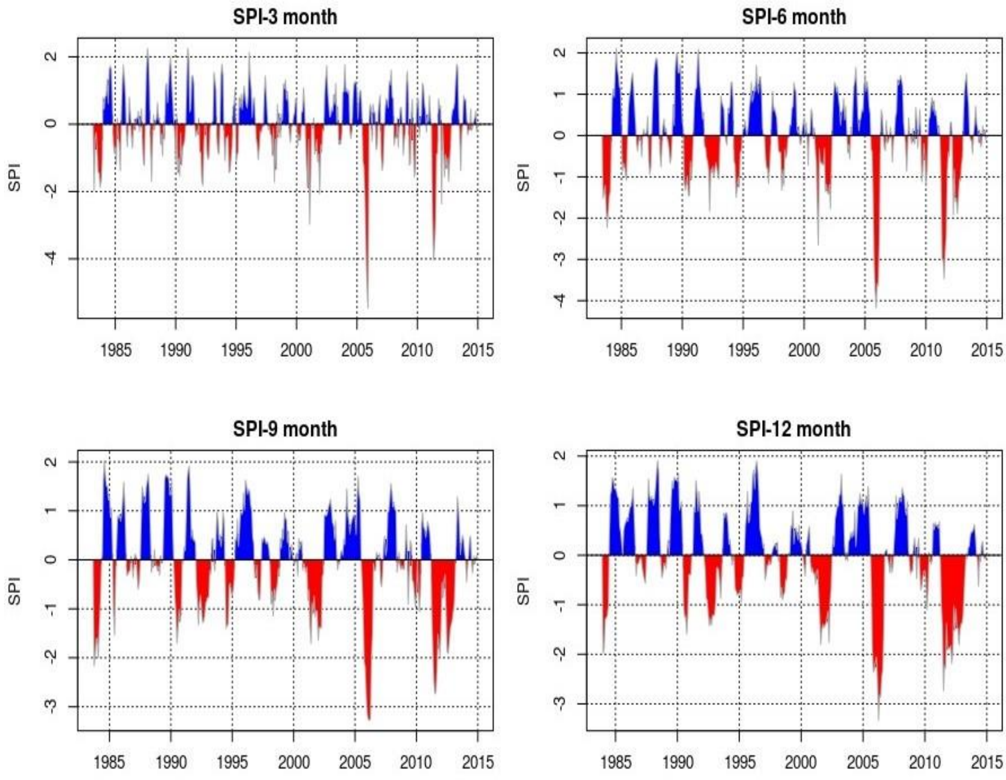

Figure 8: Drought and rainfall pattern in Busunya

The results indicate that alternating periods of wet and dry conditions did occur in Busunya (Nkoranza North) in all time scales throughout 1983-2014. Similarly, Logah et al. (2014) noted that portions of the transitional belt received less rainfall between 1981 and 2010. In the medium-long-time scale (1-9 month), the area rather experienced more cases of wet conditions than drought. Broadly speaking, this means that farmers in Nkoranza North experienced moderate drought conditions more frequently in the short-medium time scale than in the 12-consecutive month time scale. From the results in Figure 9, Nkoranza North was marked by severe drought condition (SPI = -1.5) before 1985. This confirms the results of a study by Quagraine et al. (2017) that mean rainfall amount has decreased throughout the 1968-1989 climatological period in the transitional zone of Ghana. This suggests that farming and other rainfall-dependent activities could be severely affected as well. Hence, farmers' vulnerability to drought could be worsened prior to 1985. However, 1985 was a period of severe wet conditions which could improve the livelihood activities of farmers in the Nkoranza area.

Generally, there were no drought conditions between 1985-1990 throughout all the time scales in Nkoranza as shown in Figure 8. The short-medium time scale SPI values indicate that Nkoranza North experienced fewer dry conditions for the period of 1985-1990 (SPI= -1.0 and less) interspersed with severe wet conditions (SPI= 1.5). The medium-long SPI trends reveal that the area received more rainfall which caused severe wet conditions (SPI = 1.5) to eclipse the minor dry conditions between 1985-1990. Hence, there were no drought conditions for the 1985-1990 period and this period can be described as 'non-drought' years for farmers in Busunya. The values imply the soil was extremely moist to support the cultivation of crops and also reduce farmers' drought vulnerability in the area. 1990-1995 was marked by more drought conditions compared to the previous years. Nkoranza North experienced moderate drought and severe wet conditions in 1995 and 1996 respectively. Furthermore, the SPI shows that there was no instance of severe drought condition between 1995-2000 (SPI=+ or -1.0 and less) in all the time scales. This implies that the impact of drought could not have any significant effect on agricultural production between 1995-2000. The SPI analysis also indicates that Nkoranza North experienced no drought in 2000. However, severe droughts occurred in 2001 and 2002 while 2003-2005 was marked by moderate wetness. The analysis shows that extreme drought occurred between 2005-2010 (SPI= -2.0 and less) in all time scales. This extreme drought occurred around 2006 and this could render farmers in Busunya vulnerable. Furthermore, compared to other periods, the 2005-2010 and 2010-2014 climatological periods experienced extreme drought conditions in all the time scales (SPI=2.0 and less) in Busunya.

In effect, severe drought conditions did occur in Busunya prior to 1985 period. There were alternating periods of wet and dry conditions in the short-medium time scale except 1985-1990. Nkoranza North experienced its severe wet conditions between 1985-1990. 1985-1990 can be described as the 'non-drought period' in Busunya whereas its worst extreme drought conditions occurred between 2006-2014 climatological period (SPI= -2.0). There were less periods of wet seasons and this implies that drought could have affected agricultural production between 2006-2014.

Drought and rainfall pattern in Wechaiu

The study also sought to describe the variation in drought and rainfall pattern in Wechaiu which is located in the Savannah agro-ecological zone of Ghana. The results of the SPI analysis are presented in Figure 9 and discussed in this section of the study.

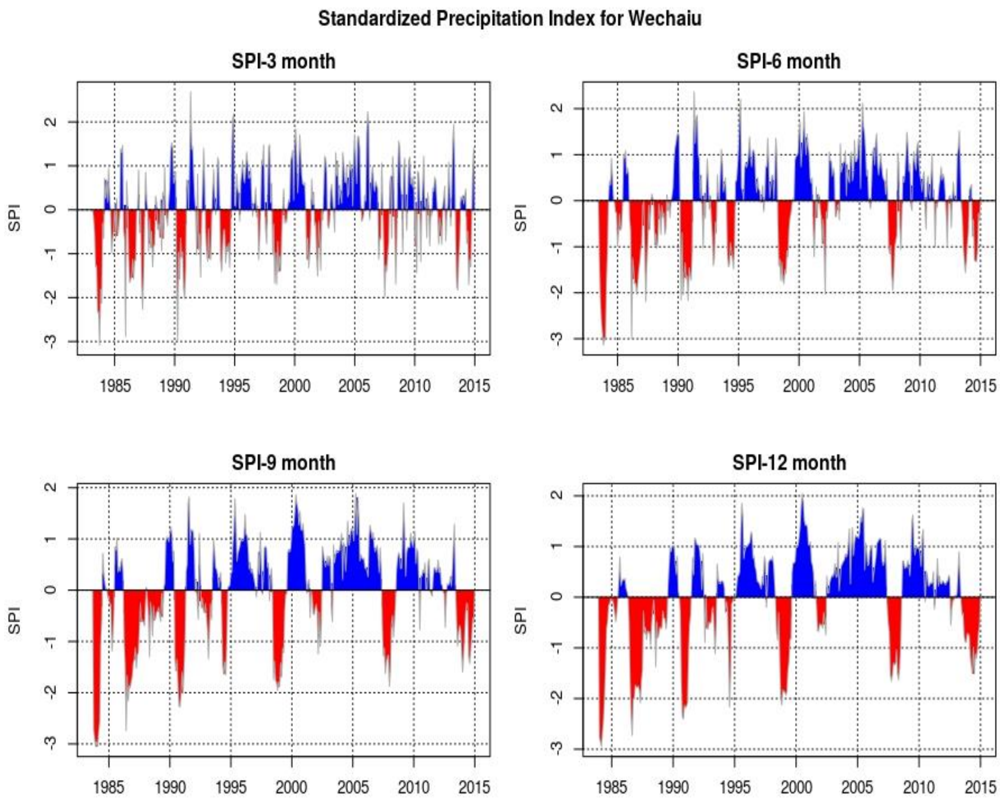

Figure 9: Drought and rainfall pattern in Wechaiu

A critical examination of the 3-month SPI displayed graphically in Figure 9 shows that Wechaiu experienced frequent and alternating periods of severe and extreme drought as well as moderate and severe wet conditions throughout the 1983-2014 period. There was an extreme drought condition (SPI = -2.0) prior to 1985 in all the SPI time scales. This was followed by extended moments of severe, moderate as well as extreme drought conditions from 1985-1990 (SPI =-1.5, -1.0 and 2.0 respectively) with moderate wet conditions (SPI=1.0) in 1990 in all the time scales. The 1983-1990 period can be considered as 'prolonged drought' years in Wechaiu when meteorological drought occurred resulting in the scarcity of water resources for agricultural and socio-economic uses. Remarkably, the SPI values indicate that there was no period of severe wetness for the 12-consecutive months for the entire 7-year period suggesting that agricultural production could have been severely hampered by drought conditions. Thus, farmers' vulnerability could have worsened during the 7-year period. This extended period of drought confirms results of a study by Logah et al. (2014) which revealed that the savannah zone receives less rains.

Furthermore, the SPI analysis reveals that 1990-1995 and 1995-2000 periods were better for farming activities compared to the previous years. This is consistent with results of a similar study by Nyadzi (2016) in parts of northern Ghana showed that high rainfall occurred around 1990-1999. An extreme drought (SPI=-2.0) occurred around 1991. This was followed with severe wet condition (SPI= 1.5) and another severe drought (SPI= -1.5) around 1994.

A severe drought occurred before 2000 (SPI = -1.5). The occurrence of severe drought could have negative implications on crop cultivation and animal production in the area. Moreover, moderate wet conditions (SPI = 1.0) prevailed after the severe drought in the 3-month, 6-month, 9-month and 12-consecutive month SPI time scales in 2000. 2000-2007 period experienced moderate and severe wet conditions. This period can be described as the 'non-drought' years in Wechaiu. Wechaiu also experienced wet conditions throughout 2000-2010. The wet conditions consistently occurred before and after the years 2005 and 2010. These years can be considered as the 'non-drought' periods for farmers in Wechaiu. However, this period of severe wet conditions was marked by a severe meteorological drought (SPI= -1.5) in the middle of 2005 and 2010 which is visible in all the SPI time scales. This implies that the area is marked by periodic droughts as observed by Yiran and Lindsay (2016). It must be emphasized that throughout the 2000-2010 period, farmers' vulnerability would be less compared to their level of vulnerability between 1983-1990 climatological period which was marked by extended period of drought. Finally, the precipitation pattern in Wechaiu was quite near normal for 2010-2013 period (SPI= .99). The area experienced moderate wet conditions (SPI = +.99) around 2010 while moderately dry conditions (SPI = 1.0) occurred in the short, medium and long-time time scales around 2014. However, the Savannah zone had no period of extreme precipitation throughout the 1983-2014 period. Likewise, Opoku-Ankomah and Cordery (cited in Owusu, 2009) also indicate that the savannah zone has distinct rainfall variability and hence receives less rainfall amounts compared to other agro-ecological zones in the country.

In sum, Wechaiu witnessed alternating periods of extreme and severe drought as well as moderate and severe wet conditions throughout 1983-2014. The area had four cases of extreme drought. The SPI values in Figure 9 also illustrate that Wechaiu experienced extreme drought conditions (SPI = -2.0) between 1983-1990. Throughout the entire 31-year period under consideration, Wechaiu had single incidence of extreme wet condition around 2000. Wet conditions occurred between 2000-2010. These wet conditions consistently occurred before and after the years 2005 and 2010.

Chapter summary

Chapter Five is devoted to the presentation and discussion of SPI results which show the pattern of drought for 1983-2014 climatological period. The results are presented and discussed based on the three selected agro-ecological locations namely Daboase, Busunya and Wechaiu. The SPI for each zone is visualized graphically representing 3-month, 6-month, 9-

month and 12 consecutive month time scales. It was found that all the selected agro-ecological locations experienced periods of extreme precipitation at some points in the 1983-2014 climatological period. However, in the short-medium time scale, incidence of drought was normal to farmers in the selected areas for the previous years. Periods of moderate, severe and extreme droughts have been interspersed with moderate and severe wet conditions in the selected agro-ecological locations throughout 1983-2014. Prior to 1985, all the selected areas except Busunya experienced highly extreme drought conditions. There was an extreme drought in Daboase prior to 1983, in 1991 and 1999. Nkoranza had its extreme drought condition between 2005-2010 and 2010-2014 climatological period. Wechaiu had incidences of extreme drought between 1983-1990 as well as around 1991 and 1999.

Incidence of drought exhibits degrees of severity and spatio-temporal variations. After 1985, Daboase and Busunya were marked by moderately wet conditions. The non-drought period in Nkoranza North occurred between 1985-1990 while Wechaiu witnessed extended moments of extreme drought conditions from 1985-1995 while 1990-1995 was marked by severe drought conditions in all the time scales. The period from 1983-1995 can be considered as 'prolonged drought years' in Wechaiu. Wechaiu had another severe drought before 2000 whereas severe precipitation occurred around 2000, 2005 and 2010. However, in the 2005-2010 climatological period, there were moderate wet periods in Daboase while Nkoranza experienced extreme dry conditions for the period interspersed with moderate wet conditions around 2007.

Between 1990-1995, Daboase had quite severe extended drought while 1992 was punctuated by severe wet conditions. Wechaiu had extended periods of quite extreme and severe drought conditions between 1983-1995 with moderate wet conditions in 1990 and 1996. Busunya had a non-drought period between 1985-1990. The area, however, experienced moderately wet conditions as well as moderate drought between 1990-1995 while Daboase was moderately wet with no periods of drought between 2005-2010. This period marked the non-drought years in Daboase whereas 2000-2005 can be regarded as the non-drought period in Wechaiu.

The rainfall patterns in Daboase approximated a near normal condition for the period of 2000-2010 where wet conditions persevered more than dry periods in the long-term time scale. Wechaiu received severe wet conditions around 2005 with severe drought mid-way between 2005-2010. Similarly, Nkoranza had an extreme drought between 2005-2010. Finally, with the exception of Wechaiu which experienced severe drought around 2014, non-drought periods lingered in both Daboase and Busunya in 2014. Wechaiu witnessed moderate wet conditions between 2010-2013 with severe drought around 2014. Drought conditions still prevail in all these areas and these can produce negative impacts on agriculture and farmers' livelihood strategies.

CHAPTER SIX

FARMERS' VULNERABILITY TO DROUGHT IN THREE AGRO-ECOLOGICAL LOCATIONS IN GHANA

Introduction

One of the greatest threats to the human race in the 21st century is climate change (IPCC, 2007). Human activities are vulnerable to the adverse effects of climate change and variability. Climate change can drastically reduce the quantity and quality of suitable arable lands, the lengths of the cropping seasons and the level of crop productivity and yields. It is projected that food production from red-fed agriculture will reduce by 50% in the year 2020 as a result of climate change. This will consequently exacerbate the level of poverty and malnutrition along arid and semi-arid margins of African continent (IPCC, 2007). The African continent suffers most from the adverse effects of climate change and variability owing to its weak social and natural systems as well as its low adaptive capacity (Stanturf et al., 2011).

Natural climate change and variability initiates drought which differs from other natural climatic hazards such as floods, hurricanes, high temperatures, high winds, and low relative humidity, among others (Sivakumar, et al., 2011). It is commonly associated with periods of departure from normal precipitation resulting in soil moisture deficit for crops, reduction in surface and underground water supply and physical water shortage to meet the socio-economic demands of mankind. According to Wilhite (2000), Makoka (2008) and United Nations (2010), drought is the most costly and deadliest of all climate change events. The impacts of drought is borne by farmers and their activities as a result of deficient soil moisture and high evapo-transpiration (Polthanee, Promkhumbut & Bamrungrai, 2014).

The occurrence of drought has implications on rural farmers. Numerous studies (Etwire, Al-Hassan, Kuwornu & Osei-Owusu, 2013; Mensah-Bonsu, Sarpong, Al-Hassan, Asuming-Brempong, Egyir, Kuwornu & Osei-Asare 2011; Yaro, 2013) have revealed that farmers are vulnerability to drought. However, these authors argued that farmers' vulnerability to drought is not evenly distributed across regions but varies according to various geographic contexts. Vulnerability to disaster differs from individual person to person and nations to nations (World Bank, 2010; Zarafshani, et al., 2016). The factors that render a pastoral community in developing country vulnerable to drought could differ from an urban area in affluent industrialized nation. Even within one community, the degree of drought related vulnerability is not likely to be same (Brooks, Adger & Kelly, 2005; Smit & Wandel, 2006). This stock of literature supports the theory of vulnerability which indicates that climate change impacts and vulnerability may vary across different agro-ecological zones (Oliver-Smith, 2004; Zakour & Gillespie, 2013.

Ghana exhibits spatial vulnerability to the adverse effects of drought which can be social, economic and environmental. Evidence suggests that half of the regions (Western and Brong Ahafo Regions) in the country exhibits medium vulnerability to climate change whereas a third (Greater Accra and the Ashanti Regions) with the highest adaptive capacity is less vulnerable to climate change. The remaining Upper West, Upper East and Northern Regions are highly vulnerable to the impact of climate change (Antwi-Agyei, 2012; Yaro, 2012).

Drought can impose limitations on agricultural productivity. Maize production in Ghana is projected to reduce by 7% in 2020 as a consequence of drought (EPA, 2008). Drought serves as a major constraint to farming communities that mainly depend on natural rain. During incidence of drought, farmers' occupation and general well-being is hampered and their vulnerability status may increase. However, rain-fed agriculture forms the backbone of the economic activities of communities in the selected study areas. For instance, crop farming (96.1%) is the major activity undertaken by households that engaged in agriculture in the Wassa East District while the predominant agricultural activity in the WWD is crop farming (97.2%). Similarly, agriculture forms over 80% of the economic activities in the Nkoranza North District (GSS, 2014). Rainfall pattern in these areas has not only changed but has become unpredictable and the amount received has also drastically reduced leading to drought conditions (GSS, 2014; Antwi et al., 2015). This creates unfavourable conditions for farmers and their agricultural activities. Farmers may attempt to reduce their drought vulnerability through adaptation. However, some farmers may possess weak adaptive capacity. Generally, farmers who lack adaptive capacity are vulnerable to the adverse impact of drought. However, Yuga, Shivakoti and Sylvain (2010) have acknowledged that local level assessment of climate-induced vulnerability has been largely ignored.

Methods

A random sample of 326 crop farmers were involved in this study. Six lead farmers were also purposively selected. Household questionnaire, key informant interviews and focus group discussions were used to collect data from the selected household farmers in the study areas.

Data was analysed using Excel and SPSS. Descriptive statistics (frequencies and percentages) and index ranking (Weighted Average Index [WAI]) were used to analyse the data on farmers rating of the socio-economic and environmental impacts of drought. Farmers' responses for drought impacts were rated by using a four-point scale with the scoring order 3, 2, 1 and 0 as 'high', 'moderate', 'low' and 'not at all' respectively. The formula for the WAI analysis is as follows:

$\frac{\Sigma F_i W_i}{\Sigma F_i}$ where *F* = frequency; *W* = weight of each scale; *i* = weight; (Adesoji & Famuyiwa, 2010; Devkota, Cockfield & Maraseni, 2014; Falola & Achem, 2017; Ndamani & Watanabe, 2016; Uddin et al., 2014).

Furthermore, index values were computed for each of the three components of vulnerability. Finally, the Drought Vulnerability Index (DVI) for each zone was calculated by using the formula:

DVI = Exposure [E] + Sensitivity [S] – Adaptive Capacity [AC]

The drought vulnerability for each zone is a composite indicator quantified by the weighted aggregation of exposure and sensitivity minus adaptive capacity. This is because adaptive capacity has inverse functional relationship with vulnerability.

Kruskal-Wallis test, a non-parametric alternative of Analysis of Variance (ANOVA) was used to statistically test for any significant variation between the three agro-ecological locations and their levels of vulnerability. Kruskal-Wallis test was used because the data did not satisfy the assumptions of normality and homogeneity of variance which are necessary for conducting

ANOVA. The qualitative data was first transcribed and coded. The data was sorted and then organised into notable patterns, categories and themes for thick descriptions. The qualitative data was presented and discussed to support the results of the quantitative data.

Results and discussion

This chapter focuses on farmers' vulnerability to drought. It presents a discussion on farmers' perceived level of drought exposure, socio-economic and environmental impacts of drought in the selected agro-ecological zones. Finally, the vulnerability of farmers to drought in the various agro-ecological zones is also being discussed in this chapter.

Farmers were asked to rate their perceived level of exposure to drought. The results that were gathered are presented in Table 6.

Table 6: Farmers' perceived level of drought exposure (N=326)

Statements	Scale	Study areas			Overall n (%)
		Daboase (n=110) n (%)	Busunya (n=140) n (%)	Wechaiu (n=76) n (%)	
Severity of drought in previous years (before 2017)	Low	6(5.5)	2(1.4)	0(0.0)	8(2.5)
	Moderate	11 (10.0)	2(1.4)	3(3.9)	16(4.9)
	High	52(47.3)	46(33.3)	38(50.0)	136(42.0)
	Very high	41(37.3)	88(63)	35(46.1)	164(50.6)
Severity of drought (2017)	Low	45(40.9)	10(7.0)	1(7.1)	56(17.2)
	Moderate	47(42.7)	73(52.1)	6(7.9)	126(38.7)
	High	9(8.2)	34(24.3)	28(36.8)	71(21.8)
	Very high	9(8.2)	23(16.4)	41(53.9)	73(22.4)
Frequency of drought occurrence (before 2017)	Low	5 (4.5)	2 (1.4)	0(0.0)	7(2.1)
	Moderate	8(7.3)	7(5.0)	4(5.3)	19(5.8)
	High	51(46.4)	23(16.4)	28(36.8)	102(31.3)
	Very high	46(41.8)	108(77.1)	44(57.9)	198(60.7)
Frequency of drought occurrence (2017)	Low	58(52.7)	6(4.3)	1(1.3)	65(19.9)
	Moderate	39(35.5)	78(55.7)	3(3.9)	120(36.8)
	High	11(10.0)	34(24.3)	32(42.1)	77(23.6)
Severity of drought impact on water supply (2017)	Very high	2(1.8)	22(15.7)	40(52.6)	64(19.6)
	Low	5(4.5)	2(1.4)	0(0.0)	7(2.1)
	Moderate	8(7.3)	7(5.0)	4(5.3)	19(5.8)
	High	51(46.4)	23(16.4)	28(36.8)	102(31.3)
	Very high	46(41.8)	108(77.1)	44(57.9)	198(60.7)
Severity of drought impact on agricultural use (2017)	Low	10(9.1)	2(1.4)	0(0.0)	12(3.7)
	Moderate	10(9.1)	7(5.0)	1(1.3)	18(5.5)
	High	35(31.8)	16(11.5)	21(27.6)	72(22.2)
	Very high	55(50.0)	114(82.0)	54(71.1)	223(68.6)

Source: Field survey (2017)

From the results presented in Table 6, most farmers in Daboase in the Forest agro-ecological zone (47.3%) rated the severity of drought in the previous years as high while only six (5.5%) indicated that drought severity in the previous years (before 2017) was low. The result is highly suggestive that droughts condition was severe in prior to 2017. A male key informant in the Forest zone explained that:

About two years ago, there was a severe drought in this area which caused damage among farmers. Farmers lost their cocoa plants especially the seedlings as a result of this severe drought (Male informant, Forest zone).

Furthermore, a majority of farmers in Busunya in the Transitional zone (63.0%) rated the severity of previous drought as very high. The views of farmers in these agro-ecological zones were collaborated by other farmers in the Savannah zone where most farmers (50.0%) also considered drought severity in the previous years as high. The results as shown in the Table 6 also suggest that before 2017, drought was severe in the selected agro-ecological zones in Ghana. This means that previous farming activities in these zones could be affected by drought and this could increase their vulnerability status.

Moreover, the severity of drought in 2017 was rated by most farmers in Daboase and Busunya (42.7% and 52.1% respectively) as moderate. This implies that drought condition was moderate in both the Forest and Transition belts of Ghana in 2017. Similarly, a male key informant in the Forest zone indicated that:

This year (2017), drought is not severe in this place but it poses problems to us (Male farmer, Forest zone)

However, most farmers in Wechaiu in the Savannah agro-ecological location (53.9%) were of the view that the severity of drought in 2017 was very high. The variation in drought severity among these areas is as results of rainfall variability between the north and south. This finding reflects results of Opoku-Ankomah and Cordery's study (cited in Owusu, 2009) which showed that there is distinct rainfall variability between the Savannah zone and the remaining Transitional and Forest zones of Ghana. This situation could have varying implications on farming activities in the selected areas in 2017. Thus, farming and other livelihood activities that are rainfall-dependent in these areas could be moderately affected by drought whilst rain-fed livelihood activities in the Savannah agro-ecological zone could be highly affected by drought in 2017. This further suggests that farmers' vulnerability to drought could vary in the selected areas.

The study reveals also that 46.4% and 41.8% of the participants Daboase in the Forest zone rated the frequency of drought occurrence in the previous years as 'high' and 'very high' respectively (see Table 6). This means that drought occurred on a high frequent basis prior to the 2017 farming year in the Forest zone of Ghana. The results in Table 6 also point out that most farmers in Busunya and Wechaiu (77.1% and 57.9% respectively) perceived the frequency of drought occurrence in the previous year as 'very high'. For instance, a male discussant retorted that:

> *Drought is common in this area and it severely affects crop production. This is very frequent. Even rain fails to fall at the time we expect it to rain* (Male Discussant, Transitional zone).

Generally, farmers in the selected agro-ecological locations reported that drought occurred on high regular basis in the previous years (before 2017). This relates to the downward trend in the rainfall pattern throughout the country. This confirms the results of various studies (Baidu et al., 2017; Gyau-Boakye & Tumbulto, 2000; Owusu, 2009) that a below normal rainfall occurred in almost all the agro-ecological zones between 1901–1905, 1908–1920, and 1980–2010 except at Kete-Krachi in Transitional zone.

The study also reveals that out of the 326 farmers, a majority of 198 (60.7%) perceived the frequency of drought occurrence in past years as very high while in 2017, most farmers (36.8%) perceived that the frequency of drought occurrence as moderate. This means that generally the frequency of drought occurrence in past years is more than its frequency in 2017. The views of participants are evocative that the frequency of drought occurrence in 2017 seems to differ from its occurrence in the previous years except in the Savannah zone. Furthermore, the results as presented in Table 6 indicate that majority of farmers in the Forest zone (52.7%) rated drought frequency in 2017 as low while most farmers in the Transitional zone (55.7%) perceived drought frequency in 2017 as moderate. This means that drought occurred less and moderately frequent in the Forest and Transitional zones respectively of Ghana. However, most farmers in the Savannah zone (52.6%) indicated that the frequency of drought occurrence in 2017 is very high. The results imply that drought occurrence was less frequent in Forest and Transitional belts whilst its occurrence was very high in the Savannah zone of the country. Thus, in 2017, the frequency of drought occurrence reduces from north toward the south. Rainfall totals tend diminish from south to north. This is because the

Savannah zone receives less rainfall amounts compared to other agro-ecological zones in the country and this results in periodic droughts in the Savannah belt (Yiran & Lindsay, 2016).

From the results in Table 6, 51(46.4%) and 46 (41.8%) farmers in the Forest zone rated as 'high' and 'very high' respectively the severity of drought impact on water supply for domestic use. Furthermore, 108 (representing 77.1%) out of the 140 farmers indicated that drought had very high severe impact on water supply in the Transitional zone. Similarly, most farmers in the Savannah zone (57.9%) considered the impact of drought on water supply as very high. The results suggest that drought has very high impact on water supply in the selected agro-ecological zones. This is because volume of both surface and sub-surface water supply largely depends on rainfall. Hence, whenever the rain fails, it presupposes that the volume of water supply will dwindle resulting in insufficient water supply for domestic uses. Similarly, high temperatures associated with drought conditions will increase the rate of evaporation which will eventually cause a reduction in water supply. During a FGD in another community, male farmer remarked that:

> *Drought sometimes causes all water bodies to dry up and we even have to send drinking water from the house to farm. During drought, all surface water bodies in this community dry up. Even if the water body does not dry up completely, it becomes muddy and colourful. We have to rely on the borehole for domestic water supply* (Male discussant, Transitional zone).

Regarding the impact of drought on borehole and well water supply, a male key informant was of the view that:

> *Sometimes, drought makes it difficult for us to get water from the well and borehole in this community. This is because drought causes water to dry up completely or reduce in volume. At times, we have to press the pump for several minutes before water will gush out for us to fetch* (Male, key informant, Forest zone).

This result implies that the selected agro-ecological zones experience socio-economic drought. As acknowledged by Wilhite and Glantz (1985), socio-economic drought occurs whenever there is physical water shortage and insufficient water supply to meet the socio-economic demand for water.

The results as presented in Table 6 also show that most farmers across the selected agro-ecological zones (68.6%) perceived the severity of drought impact on agricultural use as very high. In an interview, a farmer indicated that:

> *Drought destroys every farming activity and there is nothing we can do to stop our crops from being destroyed when drought occurs. When we plant cassava, maize, cocoyam and other crops and drought occurs, they (crops) get destroyed by it. About two years ago, I lost my maize crops as a result of drought. During drought, we even find it difficult to uproot tubers of cassava because the soil becomes dry and hard* (A 46-year male farmer key informant, Forest zone).

Drought has very high impact on farmers because agriculture in these zones is almost exclusively dependent on rainfall and any departure from normal precipitation would impose serious negative implications on agriculture. These findings imply that precipitation deficit can be highly severe to the extent that it will create serious imbalances and reduction in groundwater recharge and surface level water supply. The results of this study concur with existing literature which indicated that drought causes shortage of water supply for domestic and agricultural use (Mawdsley et al., cited in Hisdal & Tallaksen, 2000; Mishra & Singh, 2010; Wilhite, 2011).

The study also sought farmers' views on the socio-economic impacts of drought. Table 7 shows the views of farmers.

Table 7: Ranking of perceived socio-economic impact of drought (N=326)

	Degree of impact					
	Not at all	Less	Moderate	High	WAI	Rank
Impact	n (%)	n (%)	n (%)	n (%)		
Reduction in crop yield	2(0.6)	2(0.6)	40(12.3)	285(87.4)	2.87	1
Reduction in farm income	6(1.8)	1(0.3)	34(10.4)	285(87.4)	2.83	2
Increase in food prices	3(0.9)	2(0.6)	48(14.8)	273(83.7)	2.81	3
Loss of crops	3(0.9)	9(2.8)	37(11.3)	277(85.0)	2.80	4
Shortage of food	3(0.9)	11(3.4)	70(21.5)	242(74.2)	2.69	5
Loss of livelihood activities	6(1.8)	11(3.4)	86(26.4)	223(68.4)	2.61	6
Inadequate access to water	11(3.4)	12(32.7)	75(23.0)	227(69.6)	2.59	7
Sense of hopelessness	17(5.3)	22(6.7)	73(22.4)	214(65.6)	2.48	8
Conflict over water	44(13.5)	29(8.9)	110(33.7)	143(43.9)	2.08	9
Increase in livestock diseases	38(11.7)	20(6.1)	176(54.0)	92(28.2)	1.99	10
Diseases and insect infestation	36(11.0)	33(10.1)	173(53.1)	84(25.8)	1.94	11
Migration	117(35.9)	40(12.3)	79(24.2)	90(27.6)	1.44	12

Source: Field survey (2017)

From the results in Table 7, a majority of the respondents (285, representing 87.4%) were of the view that drought has high impact on reduction of crop yield while only two (0.6%) indicated that drought could not lead to reduction in crop yield. This implies that drought leads to high reduction in crop yield. In an interview with a lead farmer in the Forest zone, he lamented that:

> *Drought causes decline in cocoa production. During drought cocoa cannot bear flowers and fruits. Drought has also led to a decline in maize production. We planted but most farmers lost their maize crops. About last two years ago, there was severe drought and some farmers lost their cocoa plants especially the seedlings* (male lead farmer, Forest zone).

This confirms the results of various studies (Makoka, 2008; Opiyo et al., 2015; Speranza, 2010; Lin et al., 2013; Shiferaw et al., 2014) that severe loss of crop harvest is a direct impact of drought. Similarly, Udmale et al. (2014) acknowledge that drought leads to reduction in the yield of cereals and horticultural crops. Out of the 12 perceived socio-economic impacts of drought that were presented to the farmers, reduction in crop yield was ranked as the first impact of drought on farming in the selected agro-ecological zones. This is because crop production in these areas mainly depends on rainfall. Therefore, crop production will be seriously affected by drought and farmers will eventually record a decrease in crop yield in moments of drought.

Drought also affects schooling in the selected farming communities. Following a focus group interview with famers, it was revealed that:

> *Drought contributes to lateness among school children. He/she has to wake up and search for water to fetch before going to school. This*

> *obviously makes the child late to school* (Male discussant, Forest zone).

In similitude to the above, another farmer also indicated that:

> *Drought causes lateness to school, absenteeism and consequent drop out among some school children. Besides attending school late after making frantic search for water, some children absent themselves and drop out from schools since their parents suffer income loss in moments of drought and hence find it difficult to raise money to pay their children's school fees* (Male discussant, Savannah zone).

Another key informant in the Forest zone remarked that:

> *It even brings hardships to us as farmers. For instance, if your ward is attending school, it becomes difficult for you to raise money to pay his/her school fees because neither cocoa nor maize produces good yield to help generate income for the individual farmer* (Male famer, Forest zone).

Furthermore, from Table 7, most farmers (87.4%) indicated that drought imposes high impact on their income. The study reveals that drought leads to reduction in income derived from farming. In an interview with a famer, it was said that:

> *Drought causes financial hardships among us because we get low yield and we cannot sell some to generate income* (64-male lead farmer, Transitional zone).

The index ranking as shown in the Table 7 indicates that reduction in farmers' income constitutes the second socio-economic impact of drought. This is because although farming is being undertaken on subsistence basis in the selected areas, most farmers derive their income from the sale of farm produce. This means that the occurrence of drought can negatively affect farming and hence cause a net loss in farmers' per capita income. This finding collaborates results of a previous study by Zarafshani et al. (2012) and Udmale et al. (2014) that drought can reduce the income levels of people in agrarian communities.

The participants were also of the view that drought imposed high impact on prices of food. The study shows that drought causes a decline in crop yield which made prices of food to increase. Increase in food prices was ranked by most farmers (83.7%) as the third socio-economic impact of drought. This is in consonance with result of a study by Shiferaw et al., 2014) which revealed that drought is associated with increased food prices. The production of food in Ghana is mainly influenced by rainfall. Therefore, the occurrence of drought will lead to supply-induced scarcity of food while people would continuously demand for food as a basic necessity for their survival. Following the pricing theory, food scarcity will obviously cause a rise in its price until an equilibrium is reached between the supply and demand of food in the market, all things being equal. Where this state of equilibrium is not met, price of food will escalate. A farmer summed it up that:

> *At times we run short of foodstuff but we would not have money to buy these food stuffs due high prices. Hence, we including the entire memberships of the family, do not eat well and therefore begin to grow lean in periods of drought* (Male discussant, Transitional zone).

Moreover, contrary to results of a study by Kromker and Mosler (cited in Zamani, et al., 2006) that drought was a blessing to farmers because food provision was obtained through food aid, the study rather shows that there was food shortage in times of drought. This is because in Ghana no measure has been institutionalised to provide food relief services to drought-hit farmers. The results as presented in Table 7 depict that loss of crops and shortage of food were ranked by most farmers (85.0% and 74.2% respectively) as the fourth and fifth socio-economic impacts of drought that were perceived as high. Drought causes a reduction in soil moisture necessary for plant growth. Any resultant increase in heat will cause crops to dry up leading to serious reduction in crop yield. This will in turn cause shortage of food among people. This confirms results of previous evidence that drought leads to loss of crop productivity SAA (Shiferaw et al., 2014) as well as food insecurity (Amponsem, 2015).

The socio-economic impacts of drought go beyond crop production and food supply. From Table 7, the results indicate that out of the 326 farmers who participated in the survey, a majority of 227(69.6%) farmers perceived drought impact on access to water as high. This means that drought makes people to have inadequate access to water. This is because surface and underground water bodies both depend on rainfall. Periods of drought would be associated with water scarcity since the volume of surface water and underground reservoir either runs out or drastically diminishes during drought. Most people in the study communities also reported inadequate access to water in moment of drought because they do not have big water reservoirs such as dams, ponds, streams and rivers that can contain water for quite longer in order to continually serve the communities in the wake of drought. Thus, these communities were bound to experience inadequate access to water whenever drought occurs. This finding confirms the existing scholarly body of knowledge which indicates that water scarcity is a consequence of climate change and drought (Hisdal & Tallaksen, 2000; Sivakumar et al., 2011; Wilhite, 2011).

Moreover, it is clear from the results presented in Table 7 that a majority of 214(65.6%) farmers indicated that drought has imposed high sense of hopelessness on them. This feeling of hopelessness could result from the cumulated effect of other impacts of drought especially loss of crops, shortage of food stuffs, reduction in crop yield and farm income and increase in heat wave. During FGD, a farmer explained that:

> *We become hopeless in moments of droughts due to shortage of food and water. We also find it difficult to obtain drinking water. There is no major river that flows through this community. So, all minor rivers and streams usually dry up during periods of drought. Water will not even be available, let alone to talk about its colour and quality* (Male farmer, Forest zone).

Farming is the main livelihood activity of people in the selected study areas. Hence, any disturbance of their main livelihood activity as result of drought would invariably render them downhearted. This is analogous to result of a study by Udmale et al. (2014) that farmers' suicide and sense of hopelessness are associated with drought.

Despite the immense socio-economic impacts of drought on farming communities, most farmers (35.9%) indicated that drought had no impact on migration of people from one community to another while 27.6% indicated that the impact of drought on migration was high. The results suggest that drought does not have huge impact on migration of people. Among the 12-perceived socio-economic impacts of drought, migration was ranked as the least. During a focus discussion, a participant explained that:

> *We [farmers] do not out-migrate as a result of drought. However, we experience reduction in crop productivity and subsequent shortage of food. Our children do not drop out of school. Just that they attend school late since they spend much to search for water to fetch* (female discussant, Forest zone).

However, the study showed that farmers in the Savannah zone temporarily migrate to parts of Brong Ahafo, Ashanti and Western regions to seek alternative of source of income. In the words of a participant,

> *Drought pushes out the most energetic people from the north in search of other means of generating income and food in the south. But they usually return when the rains return* (Male discussant, Savannah zone).

This confirms results of Jawura's (2013) study that return migration is associated with after-drought seasons in northern Ghana. Generally, most farmers do not out-migrate because they might have been used to drought conditions over the decades and probably have developed methods of coping with and adapting to drought conditions (mostly diversification to non-farming activities) instead of migrating to other places in Ghana which would not change their conditions of living. This result contradicts results of previous studies by Shiferaw et al. (2014) and Udmale et al. (2014) which commonly cited population migration as an impact of drought.

On the contrary, some farmers in the Forest and Transitional zones highlighted that moderate drought is associated with some positive benefits. During a focus group discussion, it was indicated that:

> *Every disruptive event yields some positive benefits. Drought helps farmers in some ways: it is very easy to clear and burn a piece of land for farming within two weeks. But its harmful impact outweighs its benefits* (male discussant, Forest zone).

In support of the above statement, other farmers had various perspectives on the positive side of drought:

> *We [farmers] are able to quickly dry our cocoa beans and cassava in times of drought. Indeed, it becomes difficult to uproot cassava in days of drought because the soil will be hardened. However, if you are able to get one basin full of cassava, you can price it for Gh cedis 70. Generally, prices of food stuffs increase and we able to get high income for whatever food stuffs we send to the market. But when it rains, you get a basin of full of cassava for just Gh cedis 10* (male discussant, Forest zone).

> *Drought only helps us to dry and preserve crop products like groundnuts and beans that yield before the on-set of droughts* (female discussant, Transitional zone).

> And

> *We rather process the cassava tubers into 'Konkonte' by drying since the tubers cannot be well-cooked to be used for pounding 'fufu'. At times too, we process the cassava into gari* (female discussant, Forest zone).

Paradoxically, the results suggest that farmers gain beneficially from drought periods. For instance, farmers require dry periods to process or preserve farm produce such as cocoa, cassava, beans, maize, among others. Moreover, the reduction in food produce which is usually associated with droughts is an incentive for farmers to maximize income from the sale of the little harvest made.

The study also sought farmers' views on the environmental impacts of drought. Table 8 shows the views of farmers.

Table 8: Ranking of perceived environmental impact of drought (N=326)

Impact	Degree of impact Not at all n (%)	Less n (%)	Moderate n (%)	High n (%)	AWI	Rank
Drying up of surface water	7(2.1)	8(2.5)	53(16.3)	258(79.1)	2.72	1
Increase in heat wave	2(0.6)	3(0.9)	77(23.6)	244(74.9)	2.73	2
Deterioration in water quality	3(0.9)	5(1.5)	135(41.4)	183(56.2)	2.53	3
Reduction in soil moisture	3(0.9)	8(2.5)	168(51.5)	147(45.1)	2.41	4
Decline in ground water level	3(0.9)	9(2.8)	171(52.5)	143(43.9)	2.39	5
Destruction of vegetation cover	4(1.2)	8(2.5)	193(59.2)	121(37.1)	2.32	6
Occurrence of bush fires	107(32.8)	22(6.7)	55(16.9)	142(43.6)	1.71	7

Source: Field survey (2017)

The results as shown in Table 8 indicate that a majority of farmers indicated that drought has high impact on the drying up of surface water (79.1%) and as well deterioration in water quality (56.2%). Out of the seven environmental impacts of drought identified in the selected zones, the participants ranked drying up of surface water bodies as the first impact. A participant remarked that:

During drought all surface water bodies in this community dry up. We have to rely on the borehole for domestic water supply. However, we sometimes find it difficult to pump up water due to a decline in underground water level in period of drought (Male discussant, Transitional zone).

Hmmm! All water bodies in this area dry up when drought occurs. This is because there is no major river that flows through this community. All minor rivers and streams usually dry up during periods of drought. Water will not even be available let alone to talk about its colour and quality (Male discussant, Forest zone).

An interview with other farmers indicates that the story is worse in the Savannah zone. A participant alleged that:

Besides the Black Volta which is quite distant away, there is no other major river and stream in this place. We have a small dam which sometimes dries up completely or gets muddy during droughts. Even drought has been causing the level of water in the Black Volta to sharply decline. So, we [human beings] and our livestock find it difficult to access water in times of drought. Some livestock get famished due to shortage of water and feeds in times of drought (Male discussant, Savannah zone).

This is because all surface water bodies in these areas are minor ones which are fed by rainwater. This presupposes that any departure from normal precipitation would obviously lead to reduction in the water supply to the water bodies. Continuous exposure of these water bodies to heat and prevailing winds will increase evaporation and the subsequent drying up of these water bodies. This confirms Diaz, Hurlbert and Warren's (2016) view that drought affects availability of surface or subsurface water supply.

The subsequent drying up of surface water bodies could be attributed to increase in heat wave usually associated with periods of drought. As previously found by Udmale et al. (2014) that drought posed such environmental impacts as extreme heat and temperature, this study similarly indicates that most farmers (74.9%) perceived increase in heat as the second highest environmental impact of drought. In a focus group discussion, a farmer commented that:

> *During drought, there is too much heat in our rooms and most people also get malaria at that time since they tend to sleep outside* (Male discussant, Forest zone).

> *Soil becomes hot and hard for soil organism (worms and termites) to operate in the soil. Some even die as a result of drought* (Male discussant, Transitional zone).

Rains moderate extreme temperature conditions. It therefore follows that the absence of rains would pave way to extreme temperature especially increase in heat wave.

Moreover, the study reveals that drought has moderate impact on decline in soil moisture and ground water levels as well as destruction of vegetation cover. The qualitative results indicate that drought reduces soil moisture content. A key informant said that:

> *I have ever lost my maize crops as a result of drought because the soil became dry and hard* (A male lead farmer, Savannah zone).

These are moderate impacts of drought because these aspects of the environment are not usually affected by drought. Soil moisture and groundwater will only decline in the long run in the absence of rains. Similarly, the vegetal covers of these zones are quite resistant to the prevailing climatic conditions and would only be affected in the long-run in the wake of drought.

Finally, the results presented in Table 8 show that participants rated the occurrence of bush fires as the least environmental impact associated with drought. This implies that despite drought conditions, the environments of these areas are not greatly threatened by the menace of bush fires. This is because these agro-ecological zones do not usually experience drought conditions that predispose the vegetation to bush fires. Another reason could be due to the ban imposed on bush burning in the country. During an interview, it was reported that:

> *As a lead farmer, we have enforced a law that prevents farmers from burning bushes. Those who even need to burn their farms have been warned to be extra-careful. Hence, we hardly experience bush fires in this place* (Male lead farmer, Forest zone).

Vulnerability index for agro-ecological locations

As previously indicated, the average weighted method using Excel was employed to compute the indices for the three components of drought vulnerability as defined by IPCC. The results are presented in Table 9.

Table 9: Vulnerability index for agro-ecological locations

Agro-ecological location	Exposure (E)	Sensitivity (S)	Adaptive capacity (AC)	Vulnerability [(E+S)-AC]
Savannah	0.36	0.28	0.15	0.49
Transitional	0.32	0.21	0.12	0.41
Forest	0.35	0.13	0.13	0.35

Source: Field survey (2017)

It is indicative from the indices in Table 9 that the farmers in Wa West in the Savannah agro-ecological location has the highest vulnerability index (0.49) compared to farmers in Nkoranza North in the Transitional zone (0.41) and the Daboase in the Forest zone (0.35). Similar to Yaro’s (2013) study which indicated that there is spatial vulnerability to climate change in Ghana, this present study also reveals that the Savannah zone with the highest drought sensitivity (0.28) is most vulnerable to drought, followed by the Transitional zone while farmers in the Forest zone have the least vulnerability to drought. These findings confirm the results of previous study by Antwi-Agyei et al. (2012) which indicated that the Savannah agro-ecological zone is the most vulnerable to the impact of climate change.

The results further show that farmers in the Savannah zone have the highest adaptive capacity (0.15) while those in the Transitional zone have the least adaptive capacity (0.12) among all the selected agro-ecological locations. The high adaptive capacity of farmers in the Savannah zone can be attributed to the location of its selected farming communities and their farmlands. For instance, farmers in Dorimon utilize the wetlands along the River Black Volta while some farmers in the Vieri community also undertake crop cultivation even during the dry season due to their proximity to a river and irrigation system in Siyiri. These communities are also engaged in livestock production which gives them an edge over their farming counterparts in other places. Thus, farmers in these areas tend to possess higher adaptive capacity. However, they still have the highest vulnerability to drought due to the fact that the zone has the highest potential impact of drought, namely exposure (.36) and sensitivity (.28).

Furthermore, Wassa East in the Forest zone has the second highest drought exposure (.35). However, this zone has the least index for drought sensitivity (.13) and this explains why its total drought vulnerability index (.35) is the least among all the three agro-ecological locations. This can be attributed to the fact that the Forest agro-ecological zone has less cases of extreme drought conditions compared to the Savannah and Transitional zones. Moreover, most farmers in the forest belt cultivate tree crops which are less vulnerable to the impact of drought.

Kruskal-Wallis test was conducted to investigate the possibility of any statistical difference between the agro-ecological locations and their vulnerability to drought. Table 10 shows the results.

Table 10: Results of Kruskal-Wallis test on difference between agro-ecological location and vulnerability (N=326)

	Agro-ecological location	N	Mean rank	>median	<median
Vulnerability	Forest	110	78.75	11	99
	Transitional	140	186.19	82	58
	Savannah	76	244.38	68	8

NB: Chi-Square statistic= 153.10; df= 2; Asymp. Sig.= .000 at .05

Source: Field survey (2017)

As a complementary analysis to the drought vulnerability index in the preceding Table 10, the mean ranks of the Kruskal-Wallis test in Table 10 further show that there is spatial variation in drought vulnerability across the Forest, Transitional and Savannah agro-ecological locations in Ghana. The mean rank vulnerability for Savannah zone (mean rank =244.38) is the highest, followed by the Transitional zone (mean rank =186.19) and lastly the Forest zone (mean rank = 78.75). The test further reveals that the agro-ecological locations differ statistically significant in their levels of drought vulnerability (Chi-square statistic= 153.10, df= 2, p<.05). Thus, farmers in the Savannah zone are more vulnerable to drought than farmers in the Forest and Transitional zones. The resultant median test in Table 10 indicates that out of the 76 farmers in the Savannah zone, 68 farmers representing 89.5% had cases of vulnerability to drought above the median. This means that there are more cases of drought vulnerability among farmers in the Savannah zone. Moreover, out of the 140 farmers in the Transitional zone, 58.6% of them (82) had cases of drought vulnerability above the median. However, 99 farmers (that is 90.0%) out of the 110 farmers in the Forest zone had cases of drought vulnerability below the median. This means that there are less cases of drought vulnerability among farmers in the Forest zone while farmers in the Savannah and Transitional agro-ecological locations of Ghana have more cases of drought vulnerability. The results provide evidence to support the theory of disaster vulnerability which states that disaster vulnerability is not evenly distributed across regions but varies across geographic contexts (Zakour & Gillespie, 2013). The result further confirms Yaro's (2013) acknowledgement that there is spatial vulnerability to climate change in Ghana.

Chapter summary

Chapter Six presents the results on farmers' vulnerability to drought. Farmers' perceived level of drought exposure, socio-economic and environmental impacts of drought in the selected agro-ecological locations are also presented and discussed in this chapter. Finally, the vulnerability of farmers to drought in the various agro-ecological zones is also being discussed. It was revealed that drought is a common phenomenon in all the selected agro-ecological locations of Ghana. It imposes adverse impacts on farmers and this affects their livelihood activities. Drought imposed very high severe impact on water supply and agricultural activities in the three agro-ecological zones. It severely affected crop production as well as water supply. Generally, reduction in crop yield, reduction in farm income, increase in food prices, loss of crops and shortage of food were ranked as the first five socio-economic impact of drought while diseases and insect infestation, and migration were weighted as the two least socio-economic impacts of drought on farmers. Moreover, drying up of surface water, increase in heat wave and deterioration in water quality were identified as the top three environmental impacts of drought. Occurrence of bush fires was perceived by the farmers as the least environmental impact of drought.

SPI reveals that more wet cycles dominate in the Forest and Transitional areas compared the Savannah area where there are more drought periods. Farmers' vulnerability to drought differs across the three agro-ecological areas. Drought vulnerability decreases from north to south while wet cycles increases from north to south. This implies that drought vulnerability is largely determined by drought exposure and sensitivity. There is a statistically significant spatial variation between agro-ecological locations and levels of vulnerability. Comparatively, farmers in Wa West in the Savannah zone were highly vulnerable to drought, followed by farmers in Nkoranza North in the Transitional zones. Farmers in Daboase in the Forest zone had the least vulnerability index to drought. Drought exposure and sensitivity are higher in the Savannah zone compared to the Forest and Transitional zones of Ghana.

CHAPTER SEVEN

FARMERS' ADAPTATION TO DROUGHT IN THREE AGRO-ECOLOGICAL LOCATIONS IN GHANA

Introduction

All living organisms adapt differently to climate change. Authors such as Burton et al. (2006), Matthews and Sydneysmith (2010) assert that adaptation to climate change and variability is an aged-long phenomenon which clearly indicates that the climate has been changing and farmers have been adapting (Golo & Yaro, 2013). Throughout history, societies have adapted to climate variability through the alteration of settlement and agricultural patterns, and economic activities and lifestyles. Adaptation is context and place-specific (IPCC, 2014; Simpson et al., 2008; Smit & Wandel, 2006; Yaro, 2013) and different farming communities adopt different drought adaptation strategies (Luwesi et al., 2017). Usually adaptation varies across societies, there are no single prescribed adaptation measures to be used by people in different places. Yaro (2013) emphasizes that addressing climate change requires the adoption of a specific household approach rather than a general approach. Adapting to climate change varies from household to household and among individuals. Thus, there is no single prototype strategy that is appropriate for avoiding or minimizing risks across all settings. This is because effective risk reduction and adaptation measures take into consideration the dynamics of vulnerability, type of exposures and their linkages with socio-economic processes, and sustainable development (IPCC, 2014).

Drought, like any other natural disaster, imposes multiple impacts on society and there would be need to reduce its vulnerability to drought impact through effective drought planning and management (UNESCO, 2007). Drought management is a decision-making process through which society increases its preparedness for drought. Through drought planning, society identifies and develops effective ways of mitigating the losses and damages associated with drought. The planning provides decision-makers with the opportunity to lessen both expenses and sufferings that emanate from drought (UNESCO, 2007). Farmers can reduce their vulnerability to drought through planned adaptation. IPCC (2014) states that proactive adaptation is the result of conscious decision-making policy based on the awareness of climatic change and that, actions need to be undertaken in order to maintain or achieve a desired state. Proactive measures are usually taken prior to the advent of drought. However, reactive adaptation is autonomous and does not constitute conscious and deliberate response to climatic stimuli but is triggered by ecological changes in natural systems (IPCC, 2014). Whilst anticipatory adaptation strategies are predominantly ex-ante measures, reactive adaptation strategies appear ex-post in a nature.

Studies have demonstrated that adaptation strategies are numerous and their implementation processes differ from place to place (Abid et al., 2015; Balama et al., 2013; Etwire et al., 2013;). Many options are available for farmers to adapt their agriculture to climate change (Stanturf et al., 2011). Wealthy and affluent families can conveniently invest in anticipatory or proactive adaptation strategies such as use of wells and mechanized irrigation systems (World Bank, 2010). The poor and asset-less people, however, may lack the necessary resources to easily invest in adaptation.

According to World Bank (2010), common adaptation measures comprise livelihood diversification, timing and adapting to planting dates and seasons, and changes in crops planted. The increasing livelihood diversification strategies to combat climate challenges are prevalent especially among women. Since vulnerability to climate change is not uniform but varies across the axes of society, adaptation strategies also differ from place to place, largely attributable to and contingent upon social differentiation and access to resources.

Farmers possess varying degrees of adaptive capacities to mitigate the impacts of drought in order to reduce their vulnerability status. This is because farmers exhibit different socio-demographic characteristics as well as possess different resources that determine their adaptive capacities. The difference in their adaptive capacities and characteristics also determine the kind of adaptation measures that they would employ to adapt to drought. This suggests that although farmers may possess knowledge and information about drought adaptation measures, they would decide to either adopt or not adopt a particular drought adaptation measure.

Methods

The researcher used a random sample of 326 crop farmers and six purposively selected lead farmers. Household questionnaire, key informant interviews and focus group discussions were used to collect data from the selected household farmers in the study areas.

The qualitative data was first transcribed and coded. The data was sorted and then organised into notable patterns, categories and themes for thick descriptions. The qualitative data was presented and discussed to support the results of the quantitative data which was analysed using STATA 14. Pearson Chi-square test of significance was firstly employed to analyse the data on farmers' adaptation strategies across the three agro-ecological locations in Ghana. This helped to compare farmers' adaptation practices across the three selected agro-ecological locations.

Finally, binary logistic regression model (using Maximum Likelihood Estimation) was used to investigate the predictive validity of farmers' socio-demographic variables on their choice of the individual adaptation measures. Farmers socio-demographic characteristics constituted the explanatory variables while the binary outcome/dependent variables comprised selected drought adaptation strategies that were mostly adopted by farmers. According to Zakour and Gillespie (2013), the usefulness of logistic regression is rooted in the fact that the set of two or several predictors can be measured as continuous, dichotomous or discrete variables. They further indicate that "unlike linear regression, logistic regression makes no assumptions about predictor variables in terms of normal distribution or linear relationships among predictor variables" (p.78). Moreover, unlike the multinomial logit model, the use of binary logit model has an outstanding advantage since it allows for individually analysing and verifying the probabilities of adopting each drought adaptation strategy. Farmers usually adopt adaptation measures simultaneous and this renders that use of multi-nominal model inappropriate. The logit model helped analyse the influence of farmers' socio-demographic variables on the adoption of each adaptation strategy separately and independently and also helped eliminate the effects of choosing one adaptation strategy on the other (Mabe et al., 2014). Using a logit model would provide results that can facilitate the formulation of specific policies and recommendations relative to specific drought adaptation strategies. Table 3 presents a description of explanatory variables used in model.

Model specification

Following the methods of Greene (2003; 2007),

$$Log\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \sum_{i=1}^{n} \beta_i X_I$$

The probability of adoption can be expressed in the logit equation with cumulative distribution function as:

$F(\beta^1 x) = P_i(Y_i = 1) = \frac{\exp(\beta_i \beta X_i)}{1+\exp(\beta_i \beta X_i)}$

where β' represents the vector of parameters associated with the factors *x*. However, the probability of non-adoption of particular adaptation measure is written as: $P_i(Y_i = 0) = 1 - P(Y_i = 1) = \frac{1}{1+e^{\beta_i X_i}}$

By assumption, the probability that a farmer will choose to adapt to drought by using a particular adaptation strategy can be estimated through a logit empirical model which is proposed and specified as follows:

$In\left[\frac{P_1}{1-P_1}\right]$ = β_0 + β_1Agro-zone + β_2Gender + β_3 Marital status + β_4 Schooling years + β_5 Experience + β_6Farm size + β_7Household size + β_8Access to credit + β_9Membership of association + β_{10} Access to extension service + ε

Where β_0, β and ε represent the intercept, vector of regression coefficients and random error terms respectively.

Model diagnosis

Prior to the estimation of the final logit model, the explanatory variables were examined to check for possible autocorrelations by using pair-wise correlation in Stata 14. This helped to remove from the final model some explanatory variables that were dependent and strongly correlated to each other. The results indicate that farming experience (measured as the number of years a participant has engaged in farming) positively correlated with the actual age of the farmer (r=.63). Age was excluded from the model in favour of farming experience since their experience in farming activities over the past years could enable them provide sound information on drought adaptation. In a similar vein, the diagnostic test reveals that household size had a moderate positive correlation with number of dependents in the family (r=.49) while a positive collinearity was found between farm size (size of farm in acres) and landholding (r=.55). Since household size is more encompassing than number of dependent and can greatly serve as labour force for farming activities, household size is used in the analysis. Instead of landholding, farm size was selected and added to the model. In all, the logit model was fitted by using 10 explanatory variables. These independent variables comprised agro-ecological zone, gender, marital status, schooling years, farming experience, farm size, household size, access to credit facilities, membership of farm-based association and access to agricultural extension service.

Results and discussion

This Chapter focuses on the presentation and discussion of results on farmers' adoption or non-adoption of various drought adaptation measures. It also discusses farmers' socio-demographic factors as determinants of drought adaptation strategies. Table 11 presents the results with respect to farmers' drought adaptation across the three agro-ecological locations in Ghana.

Table 11: Adaptation measures across agro-ecological locations (N=326)

	Forest (n=110)		Transitional (n= 140)		Savannah (n= 76)		Overall Adoption			
	A	NA	A	NA	A	NA				
Adaptation measures	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	χ^2	ρ-value	Phi
Application of agro-chemicals	60 (54.5)	50 (45.5)	127 (90.7)	13 (9.3)	48 (63.2)	28 (36.8)	235 (72.1)	43.98	0.001*	.37
Changing planting time	52 (47.3)	58 (52.7)	119 (85.0)	21 (15.0)	63 (82.9)	13 (17.1)	234 (71.8)	49.33	0.001*	.39
Migration	9 (8.2)	101 (91.8)	46 (32.9)	94 (67.1)	48 (63.2)	28 (36.8)	103 (31.6)	63.04	0.001*	.44
Cultivation of different crops	44 (40.0)	60 (60.0)	16 (11.4)	124 (88.6)	5 (6.6)	71 (93.4)	261 (80.1)	42.58	0.001*	.36
Changing location of crops	68 (61.8)	42 (38.2)	21 (15.0)	119 (85.0)	62 (81.6)	14 (18.4)	223 (68.4)	70.34	0.001*	.47
Soil moisture conservation practices	12 (10.9)	98 (89.1)	47 (33.6)	93 (66.4)	28 (36.8)	48 (63.2)	87 (26.7)	21.39	0.001*	.27
Cultivation of drought-tolerant crops	16 (14.5)	94 (85.5)	21 (15.0)	119 (85.5)	16 (21.1)	60 (78.1)	53 (16.3)	1.68	0.430^{NS}	.07
Cultivation of early maturing crops	68 (61.8)	42 (38.2)	131 (93.6)	9 (6.4)	65 (85.5)	11 (14.5)	264 (81.0)	41.66	0.001*	.36

Table 11 (cont'd)

Diversifying from farm to non-farm activities	48	62	69	71	45	31	165			
	(43.6)	(56.4)	(49.3)	(50.7)	(59.2)	(40.8)	(50.6)	4.38	0.110^{NS}	.10
Integrating crop with livestock production	53	57	84	56	47	29	184			
	(48.2)	(51.8)	(60.0)	(40.0)	(61.8)	(38.2)	(56.4)	4.68	0.970^{NS}	.12
Home gardening	50	60	48	92	32	44	130			
	(45.5)	(54.5)	(34.3)	(65.7)	(42.1)	(57.9)	(39.9)	3.41	0.180^{NS}	.10
Water harvesting practices	19	91	9	131	19	57	47			
	(17.3)	(82.7)	(6.4)	(93.6)	(25.0)	(75.0)	(14.4)	14.87	0.001*	.21
Changing size of farm land	41	69	84	56	36	40	161			
	(37.3)	(62.7)	(60.0)	(40.0)	(47.4)	(52.6)	(49.4)	12.89	0.001^{*}	.20
Drought monitoring	41	69	91	42	45	31	184			
	(37.3)	(62.7)	(70.0)	(30.0)	(59.2)	(40.8)	(56.4)	27.15	0.001^{*}	.30

Source: Field survey (2017) NB: df =2; * implies significant, NS implies not significant at .05 (2-tailed); A= Adopted; NA= Not Adopted

The application of agro-chemicals as a drought adaptation measure is significantly associated with agro-ecological locations as shown by the χ^2 (2, N = 326) =43.98, $p < .05$. It is indicative from the results in Table 11 that majority of farmers (90.7%) in Nkoranza North in the Transitional zone applied agro-chemical compared to farmers in the Daboase and Wechaiu (54.5% and 63.2% respectively) who adapted to drought through the application of agro-chemicals. Most crop farmers in Daboase in the Transitional zone adopted the application of agro-chemicals compared to other farmers in the Forest zone because the Forest oxysol soil has higher moisture holding capacity and fertility and therefore more capable of supporting crop production.

On the whole, the study reveals that most farmers (72.1%) in the selected study areas adopted application of agro-chemicals as measure to adapt to drought. This finding is consistent with results of previous studies that applying both organic and inorganic fertilizer on farmlands is a method of mitigating low crop yield associated with unreliable rainfall pattern and prolonged dry spell. Fertilization has been found to improve infiltration, soil fertility, and its water retention and transmission capacity. It also helps modify soil physical properties and hence, make crops more drought tolerant (Debnath et al., 2012; Kurothe et al., 2014; Kloos & Renaud, 2014; Pardoe et al., 2016; Wani &, 2013).

The results as shown in Table 11 indicate that majority of farmers in Daboase in the Forest zone do not resort to migration as a drought adaptation measure. Out of the 110 farmers in the Forest zone who participated in the survey, an overwhelming majority of 101 (91.8%) farmers did not employ migration while only nine farmers (representing 8.2% of the farmers) were of the view that they adopted migration as a measure to reduce their vulnerability to drought. Moreover, out of the 140 farmers in Nkoranza North in the Transitional zone that participated in the study, it was found that a greater proportion of farmers (67.1%) did not adopt migration as drought adaptation measure. Thus, migration is not a common drought adaptation strategy in the Forest as well as the Transitional zones of Ghana. This contradicts findings of Yang et al. (2015) that migration is the commonest drought adaptation strategy among farmers in the Ningxia Hui Autonomous Region of Northwestern China. Most farmers in the Forest and Transitional zones of Ghana do not adapt to drought through migration because there are various livelihood activities and crop diversification strategies which assist them to adapt to the hardships imposed by drought. For instance, various artisanal activities, trading or business ventures, seeking employment in craft and cottage industries, and other sources of off-farm income generating abound in the forest belt of Ghana and hence, most farmers in this area do not over dependent on rain-fed agriculture.

However, there are more cases of migration among farmers in Wechaiu in the Transitional zone compared to farmers in Daboase in the Forest zone. This is because some farmers in the Forest zone migrated either from the Savannah zone, Transitional zone or neighbouring communities in Cote d’ Ivoire to undertake cocoa cultivation since the rainfall pattern in the Forest is more favourable to farming activities. During a FGD with farmers in the Forest zone, a farmer explained that:

> *Some non-Akan speaking people migrated from Upper West and Cote d' Ivoire to this place in order to undertake cocoa cultivation. For the Dagaaba cocoa farmers, it was drought conditions that pushed them out of their region. Those from Cote d' Ivoire migrated to this place in response to drought and the previous political instability and violence in Cote d' Ivoire* (Male Farmer, Forest zone).

Most farmers in the Forest zone cultivate tree plants that are perennial and can withstand drought conditions. However, most farmers in the Savannah and Transitional zones mainly cultivate food crops that are more prone to destruction during drought conditions. When there are drought conditions some farmers migrate to other areas to engage in other livelihood activities. For instance, a participant in the Transitional zone revealed that:

> *During drought episodes, some energic young men migrate to other places where the soil moisture conditions are quite favourable in order to engage in tomato farming. But this is usually a seasonal, short-term migration* (Female farmer, Transitional zone).

The nature of migration among farmers is quite different in the Savannah zone. From Table 11, the results show that out of the 76 farmers in Wechaiu in the Savannah zone who participated in the study, majority of them (63.2%) indicated that farmers in the zone employed migration as a drought adaptation measure whereas 28 farmers (36.8%) were of the view that farmers do not resort to migration as a drought adaptation strategy. This implies that most farmers in the Savannah zone of Ghana migrate to various destinations particularly Brong Ahafo and Ashanti regions in order to engage in other economic activities as a measure to reduce their vulnerability to drought. A female farmer in the Savannah zone remarked that:

> *Most people in this community manage with drought conditions and its impact by migrating down south where they can easily find other income generating activities. Females travel to assist in trading and marketing activities while the energetic males travel to engage in farming, construction activities and at times*, '*galamsey*' (Female Discussant, Savannah zone).

The results suggest that farmers in the Savannah zone are more likely to adapt to drought and rainfall variability through migration to other places compared to farmers in the Forest and Transitional zones of Ghana. This parallels Van der Geest's (2011) revelation that rainfall variability and climate change slightly account for the out-migration of farmers from the three northern regions to Brong Ahafo Region of Ghana. Similarly, previous study by Bawakyillenuo et al. (2016) also revealed that migrants drift from environmentally fragile zones from especially northern Ghana to urban centres in search for alternative livelihoods.

The Pearson chi-square statistics as presented in Table 11 demonstrates that there is a statistical highly significant relationship between agro-ecological zones and farmers' adoption of migration as a drought adaptation measure χ^2 (2, N = 326) =63.0, p < .05. Migration among farmers is dependent on agro-ecological location. The phi value (.44) indicates that is a positive significant moderate difference between farmers' migration patterns and agro-ecological zones. The result means that there is significant difference between farmers in the three agro-ecological locations in terms of using migration as drought adaptation measure. This is because the severity of drought differs from one agro-ecological zone to another. Hence, the zone in which farmers are located can have moderate impact on whether or not they would adopt migration as drought adaptation measure or not.

Overall, it was revealed that out of the 326 farmers who were involved in the study, only 103 farmers (31.6%) employed migration as a drought adaptation strategy. This implies that most farmers do not employ migration as a method of adapting to drought vulnerability. This contradicts the results of a study by Adepetu and Berthe (2007) that some households have used out-migration as adaptation response and livelihood activity to offset the consequences of expected drought. Farmers instead of migrating, rather engage in other income generating activities as drought adaptation measure. Over the years, the entire country has been experiencing drought conditions and these farmers have learnt to live with drought since migrating to other place would solve their farming problems.

The study further revealed that out of the 110 farmers in Daboase in the Forest zone, most of them (89.1%) did not employ soil moisture conservation practices as method of adapting to drought. It was found that a small proportion of the farmers (10.9%) in this zone adopted soil conservation practices as drought adaptation strategy. This could be due to lack of knowledge and means on soil conservation practices. Similarly, the results show that most farmers in the Transitional zone (66.4%) as well as farmers in the Savannah zone (63.2%) did not practise soil conservation. Collectively, out of the 326 farmers that were sampled, only 87 farmers, representing (26.7%), reported that they have adopted to drought by employing soil conservation practises. Most farmers do not adapt to drought by devising means of conserving soil moisture. Most of these farmers might not have adequate knowledge on how to traditionally conserve soil moisture in times of drought. On the contrary, Nhemachena and Hassan (2007) and Apata (2011) has found that most farmers in southern Africa and Southwest Nigeria respectively have adopted soil and water conservation techniques as climate change adaption strategy.

From the Pearson chi-square statistics in Table 11, there is a statistically significant relationship between agro-ecological zones and farmers' adoption of soil moisture conservation as drought adaptation measure χ^2 (2, N = 326) =21.3, p < .05. However, this significant association was found to be weak (Phi= .27). The two variables are not independent of each other implying that adoption of soil moisture conservation practices is highly dependent upon agro-ecological zone. As previously stated, Comparatively, the soils are moister and most farmers in the Forest zone would not see the need to practise soil conservation. While farmers in the Savannah zone might not be able to conserve soil moisture because the soils usually contain little or no moisture in times of drought, farmers in the Transitional zone might find little moisture in the soils which is capable of supporting their crop until the on-set of rains.

Moreover, it was revealed that only 53 (16.3%) out of the 326 farmers in the three agro-ecological zones cultivated some sort of drought-tolerant crops as drought adaptation measure. The results show that most farmers in the all the agro-ecological location do not cultivate crops that are drought-resistant. Only a small proportion of farmers in the various agro-ecological zones indicated that they cultivated some crops that are resistant to drought conditions. Farmers non-adoption of drought-resistant crop varieties can be attributed to the fact that most farmers in Ghana do not have access to drought-tolerant crops. This contradicts the results of previous works by ATPS (2013) and Udmale et al. (2014) that rural farmers widely cultivate less water intensive and drought tolerant crops as adaptation options to drought. Moreover, the Pearson chi-square statistics demonstrates that farmers' cultivation of drought-tolerant crops did not vary significantly across the various agro-ecological zones, χ^2 (2, N = 326) = 1.68, $p > .05$. Thus, cultivating of drought-tolerant crops is independent of agro-ecological zone. The low phi value (phi= .07) indicates that there is very weak association between the use of drought-resist crops and agro-ecological zones. The results imply that that percentage of farmers who do not employ drought-tolerant crops does not significantly differ across the three agro-ecological zones. Generally, most farmers across the selected agro-ecological areas do not have access to drought-tolerant crop varieties. Therefore, most farmers irrespective of their agro-ecological location do not cultivate crops that are resistant to drought.

The results in Table 11 further show that a majority of 264 farmers (81.0%) out of the 326 farmers in the three agro-ecological zones adopted the cultivation of early maturing crops as a measure to adapt to drought. Majority of farmers in Daboase in the Forest zone (61.8%) cultivated early maturing crops. Moreover, an overwhelming majority of 131 (93.6%) out of the 140 farmers in Wechaiu in the Transitional zone and 65 (85.5%) farmers in the Savannah zone reported that they resort to the cultivation of early maturing crops to mitigate the impact of drought. The proportion of farmers who employed the cultivation of early maturing crops as drought adaptation measure is significantly different across the three agro-ecological zones as shown by the chi-square statistics, χ^2 (2, N = 326) = 41.6, $p< .05$. The Phi value (.36) further indicates a moderate association between farmers' cultivation of early crops and agro-ecological zones. Farmers have different varieties of early maturing crops that are cultivated in the various agro-ecological zones. The chi-square test indicates that adoption of early maturing crops is highly dependent upon agro-ecological zone. Most farmers in the Savannah and Transitional zones cultivate early maturing crops compared to the proportion of farmers in the Forest zone who cultivate early maturing. On the whole, most farmers cultivate crops that mature early so that the crops can grow and produce yields before the on-set of drought conditions. The results of this current study corroborate the findings of various previous studies (Balama et al., 2013; Bawakyillenuo et al., 2016; Fosu-Mensah et al., 2012; Pardoe et al., 2016; World Bank, 2010) that farmers resort to the cultivation of early maturing crops as a climate change adaptation strategy.

The study also revealed that farmers have been adapting to drought by integrating both farming and non-farming activities as similarly found by a previous study by Balama et al. (2013). From the results in Table 11, out of the 326 farmers, a little over half (50.6%) diversified from farm to non-farm income generating activities in order to adapt to the impact of drought. Majority of farmers (59.2%) who diversified from farm to non-farm income generating activities were located in Wechaiu in the Savannah zone. This is because drought has rendered farming activities in the Savannah zone less lucrative and productive. Therefore, most farmers in this zone seek off-farm employment opportunities. During a FGD in the Savannah zone, a female farmer retorted that:

> *Some people engage in petty trading and other small-scale marking activities in order to bolster themselves against drought hardships* (Female farmer, Savannah zone).

From the chi-square statistics in Table 11, the association between farmers' diversification and agro-ecological zone is not statistically significant, χ^2 (2, N = 326) = 4.38, $p >$ .05. Diversifying to other non-farm ventures is not significantly dependent upon agro-ecological zone. This means that the proportion of farmers who diversify to non-farm income generating activities does not differ significantly across the three agro-ecological zones. Thus, diversification to off-farm income generating activities is not significantly related to agro-ecological zones. Farmers' decision to either or not is has no significant relationship with the agro-ecological zone in which they are located.

The study further revealed that most farmers (56.4%) integrated livestock production with crop production as drought adaptation measure. This is because farmers seek solace in livestock rearing when their crops fail as a result of drought. Farmers do experience decline in crop productivity as a result of drought. Therefore, they have seen the need to engage in livestock rearing to augment their farming activities. Similarly, Balama et al. (2013) has found that local farmers in Kilombero District of Tanzania integrated crop farming into livestock production as a climate change adaptation strategy. Farmers therefore keep livestock such as goats, sheep, pigs, cattle as alternative source of livelihood activities. The results in Table 11 point out that most farmers in Wechaiu in the Savannah zone (61.8%) as well as those in the Transitional zones (60.0%) integrated livestock rearing with crop production compared to farmers in the Forest zone (48.2). This confirms results of a study by Bawakyillenuo et al. (2016) that integrating livestock rearing into crop production is common climate change adaptation method being adopted by farmers in rural Savannah zone of northern Ghana. This is because the vegetation and climatic features within the Savannah and Transitional zones are more favourable to livestock rearing compared to the climatic and vegetation characteristics of the Forest zone. However, the chi-square statistics, χ^2 (2, N = 326) = 4.68, $p > .05$ indicates that the proportion of farmers who employed integration of crop and livestock production as drought adaptation measure did not significantly differ across the three agro-ecological zones.

It is also evident from the results in Table 11 that there is a statistical and significant moderate association between the proportion of farmers who employed water harvesting practices and agro-ecological zone as shown by the chi-square statistics, χ^2 (2, N = 326) = 14.87, $p < .05$. A majority of 131 farmers (93.6%) in the Transitional zone and 57 farmers (75.0%) in Savannah employed water harvesting practices as drought adaption measure compared to a large number of 91 (82.7%) farmers in the Forest zone who did not employ water harvesting practices to combat drought. Most farmers in the Savannah and Transitional zones experienced severe drought conditions and acute water shortage than farmers in the Forest zone. It therefore stands to reason that farmers in the Savannah and Transitional zones need to harvest rainwater and store it for domestic use and animal consumption as well. However, farmers in the Forest may have unimpeded access to riverine water supply throughout the year since the water bodies in the Forest zone may not completely dry out during moments of drought.

The results from the Pearson chi-square test in Table 11 clearly show that the association between changing farm sizes and agro-ecological zones is statistically significant, χ^2 (2, N = 326) = 12.89, $p < .05$. Changing the size of farm as a drought adaptation measure is dependent upon agro-ecological location. This also implies that the proportion of farmers who would change their farm sizes as drought adaptation mechanism varies across the agro-ecological zones. Most farmers in the Forest and Savannah zones, that is 62.7% and 52.6% respectively, were of the view that they did not change their farm sizes as a drought adaptation measure. Following previous episodes of drought devastations, farmers in these zones are risk averse and may nurse fears of losing their farm output. Therefore, they prefer to remain in their comfort zones and would not want to either decrease or increase the size of farmlands. Some farmers in the Transitional zone are settler farmers who have been awarded fixed portions of land for farming. The native farmers have also cultivated cashew plants on their lands. The farmers therefore may find it difficult to increase their farms. Farmers in the Savannah zone may not even change their farm sizes because fertile farmlands are limited in supply and these farmers are fixated with the same parcel of land for continuous cropping year after year. Moreover, the farmers may find it unrewarding and time-consuming to clear new parcel of land for cultivation in the midst of unpredictable and scanty rainfalls.

However, majority of 84 (60.0%) farmers in Daboase in the Forest zone stated that they changed their farm sizes in order to deal with the impacts of drought. This is particularly applicable to farmers who cultivate food crops such as maize, and yams. The existence of vast fertile lands in this zone makes it possible for farmers to change their farm sizes. Even farmers who reduce their farmland may still get good yield simply because the soils are fertile and moist as well. Generally, the study highlighted that less than 50% (that is 49.4%) of the 326 farmers adapted to drought by changing the size of farmlands under cultivation. Thus, changing farm size is not a common drought adaptation measure among farmers in the Forest, Transitional and Savannah zones of Ghana.

Finally, the results as presented in Table 11 indicate that out of the 140 farmers in Nkoranza North in the Transitional zone, a majority of 91 (70.0%) farmers in this zone adopted drought monitoring as drought adaptation measure. Most farmers in the Transitional zone continuously monitor drought patterns before planting their crops so as to avoid the risk of losing their crops as a result of drought. This is true because most farmers in this zone stated that they constantly listen to weather news on radio and TV stations on daily basis. During FGD in the Transitional zone, a male farmer indicated that:

> *I always listen to 'weather man' on FM radio in order to know the on-set of rains before I even begin to prepare for farming. Sometimes before I go to farm, I have to listen to 'weather man' to know whether it would rain on that day or not* (Male farmer, Transitional zone).

Similarly, a majority of 45 farmers (59.2%) in Wechaiu in the Savannah zone indicated that they employed drought monitoring as a tool for preparing for impending drought conditions and to improve their resilience to drought vulnerability. The plurality of radio stations as well as the availability of agricultural extension officers in the study areas provide easy access to weather information. Hence, most farmers continually monitor weather and climatic conditions before they plant their crops. Regarding drought monitoring, a lead farmer in the Savannah zone hinted during an interview schedule that:

> *We do not sow arbitrarily in this area. We usually 'study' the weather pattern to predict the arrival of rains before sowing seeds* (Male lead farmer, Savannah zone).

However, majority of 69 farmers, representing 62.7% of the 110 farmers who participated in the survey in the Forest zone did not practice drought monitoring. The climatic conditions in this zone is quite conducive for agriculture. The farmers in this zone hardly experience severe drought that lasts long as compared to farmers in the Savannah and Transitional zones. Moreover, the soil in the Forest zone holds moisture. Hence, farmers in this zone do not really have to monitor the rainfall pattern as farmers in the Savannah and Transitional zones would do.

Overall, more than half of farmers (56.4%) practice drought monitoring. This shows that drought monitoring is mostly being practised by farmers as a method of adapting to drought in the selected agro-ecological zones. This confirms the results of a study by Pardoe et al. (2016) that farmers 'follow the rain' until they are well-convinced that they rain would not fail them before they sow their seeds. From the chi-square statistics, χ^2 (2, N = 326) = 27.15, $p < .05$ in Table 11, it is obvious that drought monitoring is highly statistically and significantly related to agro-ecological zones. This is because various agro-ecological zones have different amount of precipitation and soil moisture content to support farming activities. The phi value (.30) indicates that there is a moderate significant relationship between drought monitoring and agro-ecological zones. Therefore, the decision of a farmer to monitor and time drought would upon a particular zone where the is located. As previously pointed out, most farmers in the Savannah and Transitional zones monitor drought conditions whereas most farmers in the Forest zone do not practice drought monitoring as drought adaptation measure.

Another farmer gave a description of how they adapt to drought conditions by indicating that:

> *We usually weed around and sweep the dry leaves under the cashew trees to create fire belts around our cashew farms so as to prevent bush fires from burning our farms. Before a farmer can set fire on his/her cleared farmland, he/she will have to inform the Ghana National Fire Service for personnel to be brought to assist in monitoring the situation. At that time, it becomes a communal activity for all of us to go and assist in burning the cleared bush. This helps prevent the fire from spreading to destroy other neighbouring farms. Also, we start to prepare for farming by January-February. We clear and burn the lands far ahead of time and wait for the on-set of rains to sow. So, we do not wait for rains to start before we clear our lands. Where possible, we farm around wet lands where there is pool of water for us irrigate our crops, mostly vegetables like okro, tomatoes and pepper* (Male discussant, Transitional zone).

In conclusion, the study reveals that drought adaption measures differ significantly among farmers in the Forest, Transitional and Savannah zones of Ghana. This finding is in harmony with results of various studies (Abid et al. 2015; Balama et al., 2013; Bawakyillenuo, Yaro & Teye, 2016; Etwire et al., 2013; Jawura, 2014;) that climate and drought adaptation strategies are numerous and their implementation differs from place to place. This is because farmers' knowledge of drought adaption and their adaptive capacities as well as rainfall and soil properties differ from place to place. Therefore, farmers in various geographical locations would adapt to drought by adopting different mechanisms. However, the most commonly adopted drought adaptation measures comprise application of agro-chemicals, changing of planting date, cultivating different crops, integration of crop and livestock production, changing the location of crop on yearly basis, diversifying from farm to non-farm income generation activities, cultivation of early maturing crops and drought monitoring.

Factors that influence farmers' adaptation practices

Available literature demonstrates that farmers' adoption of climate change and drought adaptation strategies is influenced by several socio-economic, cultural and geographical factors (Fosu-Mensah, et al., 2012; Schilling & Remling, 2011). In furtherance to this, the binary logit regression model was used to investigate the factors that determine farmers' choice of different drought adaptation strategies. Farmers' socio-demographic variables served as the explanatory variables whilst drought adaptation measures were selected to serve as the dependent variables. The co-efficient and odds ratio of the binary logistics regression model are presented in Tables 12 and 13 respectively.

The goodness-of-fit statistics in Table 12 show that all the Likelihood statistics are negative, while the Wald (χ^2) statistics and their corresponding p-values for all adaptation models are positive and significant ($p<0.05$). Overall, all the models with predictors fit significantly better than the intercept-only model and therefore can accurately estimate the factors that determine farmers' choice of different drought adaptation strategies.

Estimated parameter coefficients are difficult to interpret meaningfully. The associated β values can also be tempting and misleading (Greene, 2003; Park, 2010). Parameter estimates only provide direction and not probability or magnitude of change (Abid et al., 2015; Etwire, 2012). In the words of Park (2010), "simply reporting these estimates is not sufficient" (p. 57). The odds ratio indicates both direction of change and the magnitude or probability of change. Therefore, both the odds ratio and parameter estimates have been used in this present study since they provide more powerful means of interpreting the determinants of farmers' choice of various drought adaptation strategies.

The study reveals that gender increases the likelihood of adopting some drought adaptation measures. The odds ratio indicates that being a female farmer, in comparison with a male farmer, increases the chance of applying agro chemicals by 1.264 times more, changing planting dates by 1.658 times more, cultivating different crops by 1.337 times more, early maturing crops by 1.587 times more, diversifying to non-farm activities by 1.015 times more and monitoring drought by 1.239 times more.

Table 12: Parameter estimates of logistic models on determinants of drought adaptation strategies (N=326)

Variables	Applying agro chemicals	Changing planting dates	Cultivating different crops	Changing location of crops	Early maturing crops	Diversifying to non-farm activities	Integrating crops and livestocks	Drought monitoring
Female	0.235	0.506*	0.290	-0.027	0.515	0.015	-0.131	0.215
	(0.291)	(0.304)	(0.333)	(0.297)	(0.340)	(0.250)	(0.251)	(0.266)
Transitional zone	2.271***	1.992***	1.795***	2.397***	2.413***	0.232	0.473*	1.539***
	(0.377)	(0.334)	(0.360)	(0.342)	(0.436)	(0.277)	(0.278)	(0.301)
Savannah zone	0.618*	2.172***	2.976***	2.525***	1.854***	1.062***	0.660*	0.812**
	(0.364)	(0.428)	(0.567)	(0.429)	(0.454)	(0.355)	(0.347)	(0.359)
Married	-0.162	-0.597	0.004	0.281	-0.601	-0.059	-0.118	0.377
	(0.427)	(0.433)	(0.427)	(0.401)	(0.480)	(0.332)	(0.334)	(0.346)
Divorced	-0.438	-1.796**	0.199	0.607	0.474	0.221	-0.650	0.255
	(0.737)	(0.713)	(0.752)	(0.739)	(0.856)	(0.597)	(0.620)	(0.641)
Separated	-0.150	-0.262	0.624	0.425	0.696	0.324	-0.443	0.0358
	(0.617)	(0.627)	(0.698)	(0.609)	(0.816)	(0.501)	(0.501)	(0.519)
Years of Schooling	0.057*	0.059*	0.057*	0.034	-0.039	0.009	-0.024	-0.041
	(0.033)	(0.034)	(0.038)	(0.034)	(0.038)	(0.028)	(0.028)	(0.029)
Experience	-0.012	-0.013	-0.001	0.007	-0.013	-0.025**	-0.008	0.005
	(0.011)	(0.011)	(0.013)	(0.011)	(0.013)	(0.001)	(0.001)	(0.010)
Farm size	-0.001	0.009	0.097**	0.0548*	0.056	0.007	0.023	0.019
	(0.023)	(0.023)	(0.040)	(0.030)	(0.037)	(0.018)	(0.021)	(0.022)
Household size	-0.071*	0.006	-0.061	-0.024	0.017	-0.017	0.053	-0.088**
	(0.040)	(0.044)	(0.046)	(0.042)	(0.053)	(0.035)	(0.037)	(0.037)
Access to credit	0.141	0.322	0.348	0.673**	0.979**	0.860***	0.768***	0.021
	(0.318)	(0.316)	(0.352)	(0.321)	(0.381)	(0.262)	(0.261)	(0.274)
Membership	0.036	0.295	-0.013	0.172	0.285	0.470*	0.250	0.537*
	(0.323)	(0.322)	(0.364)	(0.327)	(0.392)	(0.268)	(0.269)	(0.283)
Access to extension	0.463	0.160	0.082	0.462	0.246	-0.097	0.432*	1.088***
	(0.295)	(0.296)	(0.331)	(0.298)	(0.337)	(0.250)	(0.247)	(0.267)

Table 12 (cont'd)

Constant	0.165	-0.467	-0.721	-2.041***	-0.071	-0.390	-0.702	-1.000**
	(0.563)	(0.569)	(0.622)	(0.611)	(0.656)	(0.480)	(0.488)	(0.510)
Log Likelihood	-159.648	-159.836	-133.766	-160.428	-131.303	-211.419	-211.905	-188.984
Wald (χ^2)	66.78***	68.28***	58.17***	85.85***	54.58***	29.08***	22.69**	68.54***
Pseudo R^2	0.173	0.176	0.178	0.211	0.172	0.064	0.050	0.153

NB: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: Field survey (2017)

Table 13: Odds ratio of determinants of drought adaptation strategies

Variables	Applying agro chemicals	Changing planting dates	Cultivating different crops	Changing location of crops	Early maturing crops	Diversifying to non-farm activities	Integrating crops and livestocks	Drought monitoring
Female	1.264	1.658	1.337	.973	1.587	1.015	.877	1.239
Transition zone	9.690	7.332	6.022	10.993	11.165	1.261	1.605	4.659
Savannah zone	1.856	8.773	19.615	12.495	6.385	2.892	1.935	2.252
Married	.851	.551	1.004	1.324	.548	.942	.889	1.459
Divorced	.645	.166	1.220	1.835	1.607	1.248	.522	1.291
Separated	.860	.769	1.866	1.529	2.005	1.383	.642	1.036
Schooling	1.059	1.060	1.059	1.034	.962	1.009	.976	.959
experience	.987	.987	.999	1.007	.987	.975	.992	1.005
Farm size	.999	1.009	1.102	1.056	1.057	1.007	1.023	1.019
House size	.932	1.006	.941	.976	1.017	.983	1.055	.916
Access to credit	1.152	1.380	1.417	1.961	2.661	.983	2.156	1.022
Membership	1.037	1.344	.987	1.187	1.330	1.600	1.284	1.711
Access to extension	1.589	1.174	1.085	1.587	1.279	.907	1.539	2.967

Source: Field survey (2017)

Furthermore, the parameter estimates in Table 12 indicate that being a female farmer compared to male farmer positively and significantly ($p<0.1$) increases the likelihood of adapting to drought by changing planting dates. The odds ratio in Table 13 shows that female farmers in comparison to males are about 66% more likely of adapting to drought through changing planting dates (Table 13). This is because male farmers rather have more likelihood to adopt other agricultural technologies to adapt to climate change than their female counterparts (Deressa et al., 2008). Moreover, most farmers in the selected agro-ecological zones are males who have gained much knowledge and experience with respect to the on-set of rains and the suitable planting dates. They know when to plant their crops to coincide with the rains. Comparatively, they are less probable to change their planting dates and cultivate early maturing crops like the inexperienced female farmers. Contrary to the results of a studies by Shongwe et al. (2014) and Ndamani and Watanabe (2016) which found that gender was insignificant determinant of farmers' adaptation to climate change, this study reveals that gender has a positive and significant influence on adapting to drought by changing planting dates. This implies that a farmer's gender increases the likelihood of adaptation to climate change by changing planting dates. This result is similar to that of Gbetibouo (2009) that the gender of a farmer imposes location-specific influence on his/her choice of climate adaptation strategies.

In line with the *a priori* expectation of this study, the results in Table 12 show that agro-ecological location is a significant, positive determinant of farmers' selection of drought adaptation measures in Ghana. The results show that being in Nkoranza North in the Transitional agro-ecological zone compared to Daboase in the Forest zone has a positive and significant (p<0.01) influence on farmers' likelihood of adapting to drought through the application of agro-chemicals. From the odds ratio depicted in Table 13, farming in Nkoranza North in the Transitional zone can significantly increase the probability of adapting to drought through the application of ago-chemicals by 9.690 times more compared to farming in the Forest zone. Furthermore, it is evident from the results in Table 12 and Table 13 that farming in the Transitional zone, compared to being in the Forest zone, significantly (p<0.01) increases the probability of adapting to drought through changing planting dates by 7.332 times more, cultivating different crops by 6.022 times more, changing location of crops (by 10.993 times), cultivating early maturing crops (by 11.165 times) as well as monitoring drought (by 4.659 times).

In the same vein, the results show that farming in Wechaiu in the Savannah agro-ecological zone compared to Forest zone has a positive and significant (p<0.01) influence on farmers' likelihood of adapting to drought through changing planting dates, cultivating different crops, changing location of crops, cultivating early maturing crops, and diversifying to non-farm activities. Being a farmer in Wechaiu in the Savannah zone also significantly (p<0.05) increases the likelihood of adapting to drought through drought monitoring. For instance, farmers in the Savannah zone were 19.615 and 12.495 times more likely to cultivate different crops and change the location of crops respectively compared farmers in the Forest zone. This is because the Forest zone receives the highest rain totals in Ghana and its soil conditions are more suitable for farming compared to the Transitional and Savannah zones.

In another dimension, unlike the cash crop farmers in the Forest zone, farmers in the Savannah and Transitional zones are predominantly engaged in food crop production and therefore need to adopt various measures in their different zones to deal with the impact of drought. Hence, farmers in the Transitional and Savannah zones have less favourable climatic and soil conditions and therefore have higher likelihood of adapting to drought by selecting these measures. In line with the a priori expectation, the results imply that farmers' choice of various drought adaptation strategies is location-specific. The reason is that various agro-ecological zones in Ghana have significant difference in weather and climate parameters and farmers in the different zones have to adapt to drought by selecting different measures. This confirms various scholarly perspectives on climate change adaptation (IPCC, 2014; Smit & Wandel, 2006; Simpson, et al., 2008; Yaro, 2013) that adaptation is context and place-specific and different farming communities adopt different adaptation strategies to adapt to drought (Luwesi et al., 2017).

The parameter estimates in Table 12 also indicate that being married compared to being a single farmer, has no significant influence on farmers' choice of various drought adaptation strategies. However, the study shows that being a divorced farmer, compared to unmarried farmers, has a negative and significant ($p<0.05$) influence on the decision to adapt to drought by changing planting dates. The calculated odd ratio shows that divorced farmers, compared to single farmers, were 16.6% less likely to adapt to drought through changing planting dates. This implies that more cases of divorce will significantly lower farmers' likelihood of changing their planting dates. This could be due to the frustrations associated with divorce and the resultant disruption in the social network between the spouses. They may possess fixated knowledge and information on planting seasons and dates and therefore less likely to change their planting dates for fear of losing track of supposedly suitable planting dates.

Generally, the likelihood of adopting various climate change adaptation methods increases positively and significantly with farmers 'education (Deressa, Ringler, Alemu & Yusuf, 2008). This is because education increases farmers' knowledge and understanding of climatic patterns as well how to adapt to changing climatic patterns. It is found in this study that farmers' years of schooling is a positive, significant ($p<0.1$) determinant of adapting to drought by application of agro-chemicals and changing of planting dates. The parameter estimates in Table 12 also depict that the likelihood of cultivating different crops as drought adaptation measure significantly ($p<0.1$) increases with increase in the years of schooling. With all other variables being held constant, the results in Table 13 show that a one-unit increase in the number of years spent on education leads to 1.059 times, 1.060 times and 1.059 times increase in the probabilities of adopting the application of agro-chemicals, changing of planting dates and cultivating different crops as drought adaptation measures respectively. Farmers with more years of schooling are more knowledgeable about new agro-technologies and therefore more likely to adopt application of agro-chemicals as drought adaptation measures. Similarly, more educated farmers tend to possess accurate and reliable weather information and therefore more able to harmonize planting dates with rainy seasons and dates. These results confirm the findings of previous study by Abid et al. (2015) that a unit increase in farmers' years of schooling could marginally increase the probability of fertilizer application and changing planting dates.

In addition, this study shows that farming experience has ambiguous effect on drought adaptation. By holding other factors constant, it is obvious from the results shown in Table 12 that although not statistically significant, a unit increase in farming experience does decrease the likelihood of farmers' adapting to drought through application of agro-chemicals, changing planting dates, cultivating different crops, using early maturing crops as well as integrating crop and livestock production.

Table 13 shows that with a unit increase in farming experience, farmers were less likely to apply agro chemicals, change planting dates, cultivate different crops, plant early maturing crops, diversify to non-farm activities and integrate crops and livestock to adapt to drought. However, a unit increase in farming experience increases the likelihood of employing drought adaptation measures such as changing location of crops and monitoring drought. This suggests that, with increasing experience, farmers, despite all odds, stick to farm-based activities such as changing location of crops and monitoring drought as means of adapting to drought and the effect is statistically insignificant. The results imply the probability of adopting these measures does not significantly depend on farming experience which confirm Uddin et al. (2014) finding that older farmers have disincentive and poor interest in adapting to climate. However, the revelation in this study contradicts results of previous studies (Obayelu, Adepoju & Idowu, 2014; Mabe et al., 2014; Abid et al., 2015) farming experience significantly influenced farmers' decision to adapt to climate change through the use of these measures. Farmers might have gained much bitter experience from previous drought adaptation failures and therefore more reluctant to select these strategies to adapt to current drought situations. On the other hand, farming experience was found to have a significant ($p<0.05$) negative influence on farmers' adaptation to drought by diversifying from farm to non-farm activities. The results show that with a one-unit increase in years of farming experience, farmers were 97.5% less likely to diversifying from farm to non-farm activities (Refer to Table 13). This means that gaining more experience with drought conditions greatly reduces farmers quest to switch to non-farming activities since they seem to be happy with the little that they obtain from farming activities. This confirms prior results of a study by Obayelu et al. (2014) that an increase in farmers' age and farming experience could lead to a significant reduction in diversification to non-farm activities.

The study shows that apart from application of agro-chemical, increasing the size of a farm increases the odds of adopting the various drought adaptation strategies. Thus, a unit increase in farm size decreases the odds of applying agro-chemicals by 0.999 times although the effect is insignificant (Table 13). Increasing the size of farms land makes it difficult for farmers to obtain agro-chemicals to apply on the farm. All things being equal, farmers would be able to more apply agro-chemicals on smaller farm. The results in Table 12 further show that cultivation of different crops on the same parcel of land as drought adaptation measure is positively and significantly ($p<0.05$) determined by farm size. Moreover, farm size has a positive significant influence on changing the location of crops ($p<0.1$). The odds ratio indicates that a unit increase in the size of a farm under cultivation significantly increases the likelihood of farmers cultivating variety of crops on the same of land by 10.2%. The intention behind this action is that farmers rationalize and would want to maximize utility from a single parcel of farm. They would also want to safe guard themselves against any possible loss associated with cultivating and depending on mono-crop in the midst of drought conditions. Drought imposes uncertainties on farmers regarding the survival of a particular crop. Therefore, farmers would resort to mixed cropping so that the loss of one crop in the wake of drought might be compensated by the success of other crops. The results show that with the exception of mixed cropping and changing the location of crops, an increase in farm size does not significantly increase the probability of adapting most of the drought adaptation strategies used by farmers. This, according to Acquah (2011) and Ndamani and Watanabe (2016), is because adaptation investment is expensive and most farmers in the agro-ecological zones lacked the necessary financial resources to adopt. However, the study reveals that farm size positively and significantly ($p<0.01$) increases the probability of adapting to drought by changing location of crops (Table 12). From the odds ratio, farmers were 1.056 times more likely to change the location of crops once they increase their farm size by a unit. This is because increasing the farm size would pave way for farmers to vary the yearly location of their crops and cultivate different crops on the same field as well.

Furthermore, it is evident from the results in Tables 12 and 13 that the size of a household can determine farmers' selection of drought adaptation measures. From the parameter estimates presented in Table 12, it is evident that household size can significantly and negatively affect the probability of adapting to drought by application of agro-chemicals and drought monitoring at $p<0.1$ and $p<0.05$ respectively. The odds ratio shown in Table 13 indicate that a one-unit increase in household size would significantly and marginally reduce application of agro-chemicals and drought monitoring by 93.2% and .91.6% respectively. Similarly, Uddin et al. (2014) and Obayelu et al. (2014) have found an inverse but highly significant influence of family size on farmers' choice of climate change adaptation strategies. Increase in household size reduces the likely of applying agro-chemicals because farmers may channel financial resources to feed more 'mouths' associated with large households. This would drain the farmers' financial capital base and hence, weaken their ability to meet the high cost associated with modern agricultural chemicals and other inputs. Furthermore, there exists a significant inverse relationship between household size and drought monitoring because members of large households may be interestingly engaged in other social activities instead of monitoring the weather and therefore, would not have time to access weather information. In a similar vein, large families may breed social loafing where individuals would desire to economize their individual efforts in other activities instead of monitoring weather pattern. Each individual would expect others to monitor the weather and relay the information to the rest which might not be forthcoming. Increase in household size may only provide labour endowment but does no promote independent decision-making on drought monitoring and adaptation planning. Hence, large household creates 'hide in the crowd' attitude which has the potential to reduce the likelihood of adopting drought monitoring as adaptation measure.

Although the results of previous studies (Abid et al., 2015; Uddin et al., 2014) have indicated that access to farm credit has an insignificant influence on adaptation to climate change, this study has revealed that farmers' access to credit facilities can positively as well as significantly influence their choice of changing the location of crops, cultivation of early maturing crops, diversifying to non-farming activities and integrating crop and livestock production as drought adaptation measures (Table 12). Furthermore, in agreement with the a priori expectation, the study reveals that access to credit has a positive influence on choice of application of agro-chemicals, changing planting dates, of cultivation different crops and drought monitoring as drought adaptation strategies but negatively affects diversification from farm to non-farm activities. The results indicate that farmers who have access to credit, compared to farmers without access to credits would significantly ($p<0.01$) reduce the likelihood of diversification to non-farm activities. Farmers with access to credit were 0.983 times less likely to diversify to non-farming activities in comparison to farmers without access to credit (Table 12 and Table 13). This implies that farmers who get access to credit facilities are less likely to adapt to drought by switching to non-farming income activities such as petty trading and other retail ventures which are less dependent upon rainfall and soil characteristics. When farmers get access to credit, they rather undertake farm-based activities instead of switching to other non-farming activities. This collaborates results of a study by Nhemachena and Hassan (2007) that access to credits significantly influenced diversification from farm to non-farm activities among farmers in South Africa.

Moreover, the odds ratio in Table 13 indicates that farmers with access to credit, in comparison to farmers without access, are more likely to adopt all drought adaptation measures except diversifying to non-farm activities. It is also indicative from the results of the study that access to credit has a positive influence on drought monitoring although not significant. Thus, farmers who have access to credit, compared to farmers without access to credit, would probably increase drought monitoring so as to take advantage of rainy days. (Table 12 and Table 13). A farmer who gets access to credit facilities would want to invest in agro-production but not to diversifying to non-farm business. Hence, it would be more needful to practice drought monitoring since he/she has the means to undertake farming activities. This result partly confirms the results of previous studies (Abid et al., 2015; Uddin et al., 2014) which indicated that access to farm credit has an insignificant influence on adaptation to climate change.

It also emerged from the results that with the exception of cultivation of different crops on the same farm, membership of a farm-based association is positively related to all drought adaptation strategies that are employed in the three agro-ecological zones. This means that being a member of farm-based organisation increases the probability of adopting various strategies to deal with the impact of drought. This study indicates that being a membership of a farm-based organisation can significantly ($p<0.05$) increase the likelihood of diversifying to non-farm activities and drought monitoring by 60% and 71.1% respectively as drought adaptation measures (Table 12 and Table 13). Indeed, farm-based associations enhance social networking and promote information and knowledge-production and sharing among farmers. This confirms the results of prior studies (Shongwe et al., 2014; Uddin et al. 2014) that farmers' implementation of drought and climate change adaptation measures are dependent upon group membership and their social network.

Finally, the estimated parameters in Table 12 show that access to agricultural extension services is a positive and significant ($p<0.01$) predictor of adapting to drought by monitoring. Farmers with access to agricultural extension services, compared to farmers with no access to extension services, were 2.967 times more likely to practise drought monitoring. Moreover, the results show that access to extension services can increase the probability of applying agro-chemicals, integrating crop and livestock production ($p<0.05$) by 1.589 times and changing the location of crops ($p<0.1$) by 1.539 times as measures of adapting to drought. Although not significant, access to extension services is positively related to drought adaptation and farmers with access to agricultural extension services, in comparison to others without, were more likely to adopt all the seven drought adaptation measures except diversifying to non-farm activities (Table 13). The results suggest that farmers who get access to agricultural extension officers are educated on farm-based drought adaptation measures. According to a farmer,

> *Agricultural extension officer teaches us when and how to plant. The agricultural extension officer has made us understand that whenever drought occurs, we can apply ammonia fertilizer to increase the moisture level of our cocoa farm* (Male discussant, Forest zone).

Another farmer indicated that:

> *We have many contacts with agricultural extension officers. We have formed associations based on the type of crops being cultivated. So,*

the officers pay visits to discuss farming issues with us (Male farmer, Transitional zone).

The results of this study confirm Harvey et al. (2014) revelation that agricultural extension officers provide technical support to farmers. Therefore, farmers who have contact with agricultural extension officers get knowledge and information on weather and climate, new agricultural technologies and farming methods, improved crop varieties and new farming inputs and other agro-chemicals. The results imply that farmers who get access to extension services, compared to farmers who lack access to extension service, are more likely to adopt only farm-related drought adaptation strategies namely application of agro-chemicals, changing planting dates, cultivating different crops, changing the location of crops, cultivation of early maturing crops, integrating crop and livestock production and drought monitoring. Hence, contact with extension will increase the probability of adopting various measures to fight drought except diversification to non-farming activities.

Chapter summary

Chapter Seven deals with farmers' adaptation to drought. The Chapter focuses on the presentation and discussion of results on farmers' adoption or non-adoption of various drought adaptation measures. It also discusses farmers' socio-demographic factors as determinants of drought adaptation strategies. It was revealed that farmers in different geographical locations adapted to drought by adopting different mechanisms. The dominant drought adaptation measures comprise application of agro-chemicals, changing of planting date, cultivating different crops, integration of crop and livestock production, changing the location of crops on yearly basis, diversifying from farm to non-farm income generation activities, cultivation of early maturing crops and drought monitoring. Most farmers do not employ drought adaptation measures such as changing farm size, soil conservation, water harvesting practices and home gardening.

Most farmers in Daboase and Nkoranza North Districts were diversifying to non-farming ventures while most farmers in the Wa West practised migration and other farmed-based drought adaptation methods such as mixed cropping and farming. Moreover, most farmers in Wa West in the Savannah zone as well as those in Nkoranza North in the Transitional zone integrated livestock rearing with crop production compared to farmers in Daboase in the Forest zone.

Agro-ecological location acts as a major significant determinant of farmers' adoption of all the eight drought adaptation measures. Besides, agro-ecological location, farmers' choice of drought adaptation measures is also determined by other factors. Access to credit facilities increases the probability of adopting farm-based drought adaptation measures. Farmers with access to credits are less likely to diversify to non-farming activities. Application of agro-chemicals as drought adaptation measure was significantly determined by agro-ecological location, years of schooling and household size while the cultivation of early maturing crops was also significantly determined by the gender of farmers. Moreover, farmers' diversification intention was significantly determined by farming experience, access to credit, and membership of farm-based association. Besides agr0-ecological location, access to credit and agricultural extension services also significantly determined farmers' choice of integrating livestock production with crop production as drought adaptation. Changing the location of crops as drought adaptation measure was significantly determined by agro-ecological location, farm size and access to credit while in addition to agro-ecological location, household size, group membership, and access to agricultural extension services significantly determined farmers' adoption of drought monitoring practice

CHAPTER EIGHT

FARMERS' CONSTRAINTS TO DROUGHT ADAPTATION IN SELECTED AGRO-ECOLOGICAL LOCATIONS OF GHANA

Introduction

Inter-Governmental Panel on Climate Change (2007) predicts that the occurrence of climate-related events can cause food insecurity and erase all economic developmental gains already made in developing regions. The Panel further warns that changes in rainfall pattern will occur to affect the lives of billions of people due to severe water shortage and shift in crop growing season in the next decades. Most farmers depend on rainfall to undertake agricultural activities. This presupposes that any decline and deviation in rainfall amounts as a result of climate change can impose negative consequences on farmers' source of livelihood. Drought can reduce the well-being of farmers if no adaptation mechanism is put in place to offset its costly and deadly impacts on human activities.

Farmers' vulnerability to the impact of drought can only be reduced through the development and implementation of sound drought adaptation measures. Although adaptation and mitigation play complementary roles, adaptation can reduce the need for climate change mitigation as well as its related cost (IPCC, 2007). As a normal natural climatic event, efforts to deal with drought vulnerability should largely focus on adaptation and not mitigation. Building farmers' capacity is the sole avenue for drought adaptation. Droughts smack recurrently, but local people may lack the capacities, capabilities, and access to various assets to manage its impacts. Various experts (Ellis, 2000; Selvaraju, Subbiah, Baas & Juergens, 2006) contend that lack of technical assistance and access to information puts constraints on farmers' capacity to adapt to climate change. This situation makes peoples' livelihoods progressively more vulnerable.

Various factors may constrain sectoral and zonal farmers' ability to adapt to climate change. The factors act as barriers or obstacles that reduce the effective implementation of adaptation strategies (Moser & Ekstrom, 2010). These barriers are linked to socio-economic factors, mostly household asset and capital base of individuals (Ellis, 2000; World Bank (2010). Adaptation planning and implementation are related to "the cost of implementing measures, poor institutional base, poor political commitment, and lack of independence of implementing agencies" (World Bank, 2010, p. 55). In instances where the role of any of these factors is compromised, household adaptive capacity will invariably be weakened.

Farmers may have knowledge and information on drought adaptation. However, these farmers may not be capable of adapting to drought because certain factors can hinder their adaptation behaviour. As argued by Ajzen, (1987; 2006) in his seminal work on the theory of planned behaviour, the perceived presence of other factors may either facilitate the execution of the planned behaviour or impose constraints on the process of executing the planned behaviour. The vulnerability of agricultural-dependent communities to climate change can be better understood through the exploration of barriers that hinder their adaptation efforts (Antwi-Agyei, 2012). Most studies have focused largely on barriers to farmers' adaptation to climate change in other national context which failed to highlight the barriers that confront rural farmers' adaptation to drought in the Ghanaian context. Hence, there was the need to provide a better understanding of the problems that confront farmers' adaptation to drought in Ghana. This chapter is devoted to constraints to farmers' adaptation to drought.

Methods

Based on results of similar empirical studies on constraints faced by farmers in adapting to climate change, a survey questionnaire with nine problems that might serve as constraints to their drought adaptation was designed and presented to a random sample of 326 farmers. The farmers were then asked to rate their perceptions of each constraint on a 5-point Likert. Six key informant interviews and six focus group discussions were also conducted to collect data from the selected household farmers in the study areas.

Descriptive statistics (frequencies and percentages) were computed for each constraint to drought adaptation. Finally, the researcher adopted the Problem Confrontation Index (PCI) as used in previous studies on problems confronting farmers to compute an index for each problem by using the index formula:

$PCI = [5(P_{SA}) + 4(P_A) + 3(P_N) + 2(P_D) + (P_{SD})]$

Where,

PCI = Problem Confrontation Index

P_{SD} = Frequency of farmers who rated the problem as strongly disagree

P_D = Frequency of farmers who rated the problem as disagree

P_N = Frequency of farmers who rated the problem as not sure

P_A= Frequency of farmers who rated the problem as agree

P_{SA} = Frequency of farmers who rate the problem as strongly agree

The qualitative data was transcribed and coded. The data was sorted and then organised into notable patterns, categories and themes for thick descriptions.

Results and discussion

The results highlight that there are several challenges that confront farmers 'adaptation to drought. It is evident from the results shown in Table 14 that a majority of 261 farmers (85.3%) agreed that shortage of water for irrigation is a problem that confronts their capacity to adapt to the impacts of drought on their farming activities. The associated PCI indicates that shortage of water for irrigation ranks first among all the problems that farmers face. This situation can be attributed to the absence of major water bodies such as dams, lakes and rivers coupled with reduced precipitation in the selected agro-ecological zones. The minor streams and rivers that flow through some of the farming communities are highly seasonal. Most of the water bodies completely dry up during dry seasons or periods of droughts.

Table 14: Constraints to farmers' adaptation to drought

Constraints to adaptation	SD		D		NS		A		SA			
	Farmers' responses (N=326)											
	n	%	N	%	n	%	n	%	n	%	PCI	Rank
Shortage of water for irrigation	15	4.6	30	9.2	3	0.9	162	49.7	116	35.6	1,312	1
Unavailability of financial resources	25	7.7	38	11.0	3	0.9	127	40.0	134	41.2	1,288	2
High cost of agricultural inputs	14	4.3	49	15.0	3	0.9	159	48.8	101	31.0	1,262	3
Inadequate labour force	30	9.2	107	32.8	7	2.1	127	39.0	55	16.9	1,048	4
Inadequate knowledge	16	4.9	143	43.9	7	2.1	112	34.4	48	14.7	1,011	5
Inadequate access to extension services	45	13.8	109	33.4	3	0.9	116	35.6	53	16.3	1,001	6
Inadequate time for planning	21	6.4	173	53.1	7	2.1	82	25.2	43	13.2	931	7
Inadequate access to weather information	70	21.5	131	40.2	4	1.2	68	20.9	53	16.3	881	8
Inadequate landholding	82	25.2	138	42.3	4	1.2	67	20.6	35	10.7	813	9

Source: Field survey (2017) NB: SD= Strongly Disagree; D= Disagree; NS= Not Sure; A= Agree; SA= Strongly Agree

During FDGs, farmers in all the selected farming communities acknowledged that all water bodies usually dry up in periods of drought. They also reported that the volume of water in boreholes reduces when drought occurs to the extent that they even find it difficult to access water for drinking and other domestic purposes. The shortage of water poses a challenge to farmers who would have otherwise wished to irrigate their farms during episodes of drought. This confirms results of a study Abid et al. (2015) that shortage of water for irrigation is challenge that limits farmers adaptation to drought. It was observed that these communities lack regular source of water supply that can be used to build irrigation facilities to serve as safety nets for farmers in moments of droughts. The farmers also complained that they do not have the capacity to develop irrigation schemes to enable them combat the impacts of drought on their farming activities. For instance, it was revealed that:

> *Our main challenge is lack of water for irrigation purpose. All water bodies dry up when drought occurs. So, we find it difficult to obtain water to even irrigate vegetables* (Male key informant, Savannah zone)

This concurs with Opiyo et al. (2015) conclusion that developing irrigation farming is beyond the initial capital investment of many household and communities.

Furthermore, the results in Table 14 indicate that out of the 326 respondents, a majority of 85.3% farmers agreed that unavailability of financial resources serve as a constraint to their effort to adapt to drought. This was ranked as the 2nd problem that confronts their capacity to adapt to drought. This implies that most farmers lack credits and various forms of financial resources to adapt to drought. This is consistent with results of previous research that unavailability of money or credit facilities hinders farmers from adapting to climate change events. Lack of finance has been cited as the common problem that considerably hampers most farmers from adopting improved varieties of seed to combat drought (Nabikolo et al., 2012; Fisher et al., 2015; Pardoe et al., 2016). A farmer in the Forest zone had this to say in respect of limited financial resources:

> *Some farmers have money to adapt to drought. However, those farmers who have no financial resources cannot do anything to adapt to drought by pumping water to irrigate their farms. Farmers are people who are not trustworthy with credit facilities. The government does not give us loans because we would never repay it with the mindset that it is 'government money'. We are suffering financially because we cannot be entrusted with credit facilities. We do not get access to loans and other credit facilities from government to enable us engage in farming activities* (A male lead farmer, Forest zone).

Another farmer indicated that:

> *Our main constraint is inadequate financial resources. This prevents us from adapting to drought in this community. We cannot even increase the size of our farms due to inadequate financial resources. If there is money, we can even increase our farm size to reduce the likelihood of food shortage in the wake of drought* (Male discussant, Transitional zone).

Similarly, another male farmer further explained that:

> *Whatever we say is financial. We need money to dig wells and purchase agro-chemicals and equipment. Therefore, our main constraint to drought adaptation is lack of financial resources. So, we are appealing to the government to aid us financially. Without financial resources, we cannot do anything* (Male discussant, Transitional zone).

Moreover, during a FGD, a male farmer in Transitional zone added that:

> *For instance, there is a certain man in a near-by community known as Asekye. He has money and therefore is able to develop his personal irrigation scheme. With that you can undertake farming at any point in time. I even held a discussion with him to see if I can also implement his idea. He told me that it will cost me Ghana cedis 30,000 which I cannot afford. If we get irrigation scheme, it will be beneficial to us but we lack the necessary financial resources to build irrigation system* (Male discussant, Transitional zone).

Farmers who have knowledge and information on weather and climate as well as the use of modern methods of drought adaptation would find it difficult to adopt and implement these methods without access to financial resources. Farmers need access to credit facilities to enable them purchase improved seed varieties and agricultural inputs. This is in line with results of a study by Bawakyillenuo et al. (2016) that lack of fund served as constraints to farmers' non-adoption of irrigation systems, fertilizer application and other adaptation strategies in Savelugu Nanton, West Mamprusi and Kassena Nankana East

Districts of Ghana. This suggests that without financial resources, farming would be a fruitless venture in an era of limited rainfalls.

Furthermore, the farmers complained that high cost of agricultural inputs hinders their adaptive capacity to adapt to drought. From the results in Table 14 out of the 326 respondents, a majority of 260 representing 79.8% indicated that high cost of agricultural inputs serves as a constraint to drought adaptation in the selected agro-ecological zones. As indicated by the PCI, high cost of agricultural inputs was ranked the 3rd problem that confronts farmers' drought adaptation capacity. Where farmers lack financial resources and the cost of farm inputs is high, farmers would be put in precarious state to adapt to drought. During FGD with farmers in the Forest zone, a female farmer lamented that:

> *When drought occurs, insects and pests emerge to eat up and destroy the leaves of our crops. When it happens, we need to purchase agro-chemicals that can be used to kill the insects and pests. However, the prices of these agro-chemicals are high for us and we would even incur debt if we attempt to purchase these costly chemicals* (Female farmer, Forest zone).

Moreover, a male key informant in the Transitional zone was of the view that:

> *The agricultural extension officer has made us understand that whenever drought occurs, we can apply ammonia fertilizer to increase the moisture level of our cocoa farms. However, the cost of fertilizer is high and we do not have money to buy even one bag of ammonia. We are unable to purchase agricultural inputs and equipment that can help us fight drought conditions. Hence, we loss crops during periods*

of drought because the soil becomes dry (Male farmer, Transitional zone).

This implies that farmers may want to purchase improved seeds and agro-chemicals and other equipment to help improve upon their farming activities during droughts. However, they would not be able to afford since they lack the necessary financial resources to purchase the farm inputs which, according them, are costly. This confirms results of a study by Fisher et al. (2015) that high prices associated with seeds have been cited as the major reasons that accounted for farmers' inability to cultivate new drought tolerant maize varieties.

With reference to Table 14, the results also show that out of the 326 respondents, 159 farmers representing 48.8% of the respondents indicated that inadequate knowledge on how to adapt to drought did not constitute a constraint to their drought adaptation. However, 160 (49.1%) farmers responded that inadequate knowledge on how to adapt to drought served as a problem that constrains drought adaptation. Thus, the farmers were almost equally divided as to whether knowledge on drought adaptation constitutes a problem or not. Five out of every 10 farmers possess inadequate knowledge on how to adapt to drought. This result implies that the proportion of farmers in the selected agro-ecological zones who do not have knowledge on how to undertake drought adaptation is equivalent to the proportion of farmers who possess adequate knowledge on how to adapt to drought. Indeed, while some farmers lack knowledge on how to adapt to drought as found by Abid et al. (2015), other farmers still lack knowledge on how to adapt to drought and may remain helpless in moments of drought as previously pointed out (Nabikolo et al., 2012; Opiyo et al., 2015). During a FGD in the Savannah zone, a farmer stated that:

> *I have nothing to do in moment of drought. I just helplessly watch my crops to wither due no rains* (Male Discussant, Savannah zone).

However, some farmers have contacts with agricultural extension officers who educate them on improved farming techniques. This strengthens their capacity to adapt to drought conditions. Other farmers also receive weather information from mobile text and radio stations.

A male farmer commented that:

> *Sometimes, we receive mobile phone test messages on weather information* (Male farmer, Transitional zone).

Out of the nine problems that were presented to the farmers, inadequate knowledge on how to adapt was ranked 5th. The finding suggests that half of farmers in the study areas have gained knowledge and information on drought adaptation as a result of agricultural extension services, membership of farmers association, formal education and exposure to weather news and forecast. For instance, a farmer in Transitional zone remarked that:

> *We have contacts with many agricultural extension officers. We have formed associations based on the type of crops being cultivated. So, the officers pay visits to discuss farming issues with us (*Male farmer, Transitional zone).

As shown in Table 14, farmers ranked inadequate access to agricultural extension services as the 6th constraint that confronts their adaptation to drought. This suggests that inadequate access to extension services although a constraint, does not constitute major problem to drought adaptation.

Conversely, Adepetu and Berthe (2007) found that inadequate extension services constrain farmers' ability to adopt soil and water conservation practices.

Contrary to the perspective of WICCI (2011) that society has limited time frame for adaptation planning and implementation, this study indicates that most farmers (59.5%) had adequate time for adaptation planning. This means that most farmers have sufficient time to make decisions for effective adaptation to drought. This is because most of the farmers had formal education to some extent. They also had access to agricultural extension services, weather information and knowledge on how to adapt to drought. Similarly, farmers get experience from previous drought episodes which might have made them develop time to plan for drought adaptation. WICCI (2011) argued that inadequate time to plan and implement adaptation practices serve as a constraint among most female-headed households since women are usually pre-occupied with domestic responsibilities and hence, might not have more time to plan about drought.

From the results in Table 14, most of the respondents (61.7%) indicated that access to weather information is not a problem that confronts their adaptation to drought while 37.2% were of the view that inadequate access to weather information serves as a constraint to their drought adaptation effort. This means that most farmers have access to weather information. During a group interview, a participant stated that:

We [farmers] obtain weather information from 'weather man' during weather forecast in FM stations. Sometimes, we receive mobile phone test messages on weather information (Male farmer, Transitional zone).

Thus, access to weather information does not constitute a problem because most farmers receive weather information from their agricultural extension officers, TV sets, surrounding FM radios and colleague farmers. This revelation contradicts the results of previous studies which found that farmers lack access to weather information and this constituted a problem to farmers' adaptation to climate change (Abid et al., 2015; Apata, 2011; Fosu-Mensah et al., 2012; Nabikolo et al., 2012). In this study, it was found that most farmers have obtained formal education and this might facilitate their access to weather information. Similarly, farmers who have TV and radio sets would always get access to daily weather forecast and hence, would be able to adapt to climate change events, particularly drought. According to Maddison (2006) and Harvey et al. (2014), farmers' accessibility to meteorological information on climate change through contact with extension officers or other sources creates awareness and favourable condition for adoption of farming practices for mitigating climate change.

Chapter summary

Chapter Eight is focused on constraints to farmers' adaptation to drought. It was revealed that farmers have adequate access to weather information, adequate time for planning and adequate landholding. Some farmers have knowledge and experience on drought adaptation. These factors did not serve as constraints to farmers' drought adaptation. However, there are some barriers that militate against their adaptive capacity and hence, their adoption of drought adaptation strategies. The most critical barrier is shortage of water for irrigation. The communities lack vast water bodies that can be used for irrigation. This clearly demonstrates that farming ceases whenever drought occurs because the selected farming communities do no possesses irrigation systems. The available small water bodies tend to dry up with the on-set of droughts.

Moreover, unavailability of financial/credit facilities and high cost of agricultural inputs were also identified as barriers to drought adaptation. Farmers need to purchase agro-chemicals and other farm inputs to make effective use of short rain periods. However, these farmers do not have the needed financial capital and the cost of the various agricultural inputs is also high.

Finally, inadequate knowledge on drought adaptation as well as inadequate access to agricultural extension officers also pose as constraints to farmers' adaptation to drought. Some still lack knowledge and information on drought adaptation methods and technologies. They also have inadequate access to agricultural extension officers who can educate them on better modern farming technologies suitable for drought adaptation.

CHAPTER NINE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study investigated farmers' vulnerability and adaptation to drought in three agro-ecological locations namely Wassa East, Nkoranza North and Wa West Districts of Ghana. This final chapter presents an overview of the study and a summary of the methods that were employed to conduct the study. The chapter also highlights the key findings of the research. The conclusions and recommendations made as well as the areas suggested for further research are also presented in this chapter.

Overview of the study

This study was a cross-sectional survey which primarily sought to assess farmers' vulnerability and adaptation to drought in the Wassa East, Nkoranza North and Wa West Districts of Ghana. Specifically, the study examined the spatio-temporal variation in drought in the selected agro-ecological locations for 1983-2014 climatological period; determined whether there is any significant variation in farmers' vulnerability to drought across the selected agro-ecological zones and also analysed the drought adaptation strategies employed by farmers. Finally, it examined factors that constrain farmers' adaptation to drought in the selected agro-ecological zones.

The study was nested in the pragmatist orientation which adopted concurrent triangulation design of the mixed method approach (positivist and interpretivist paradigms). Therefore, both quantitative and qualitative methods were employed to collect data in order to achieve the objectives of the study. Precipitation data for the three study areas for 1983-2014 climatological period was excerpted from GMeT data base. Moreover, a random sample of

326 farmers and six purposively selected chief/lead farmers were involved in this study. In another dimension, 326 copies of questionnaire, six focus group discussions and six key informant interviews were used to collect primary data from the participants.

The data collected was processed and analysed by using both quantitative and qualitative techniques. All qualitative data were transcribed, sorted and then organised into notable patterns, categories and themes for thick descriptions based on the respective research objectives. SPI was used to analyse the drought index and hence, assess the spatial and temporal variability of meteorological drought across the three agro-ecological locations from 1983-2014. The primary quantitative data was processed and analysed with the aid of SPSS (version 22), Microsoft Excel and STATA 14. Index ranking (Weighted Average Index [WAI]) and Kruskal-Wallis test were used to analyse the data on farmers rating of the socio-economic and environmental impacts of drought and their overall vulnerability to drought. Frequencies, percentages and Pearson Chi-square test of significance were employed to analyse the data on farmers' adaptation strategies across the three agro-ecological zones in Ghana. The binary logistic regression model (using Maximum Likelihood Estimation) was used to investigate the predictive validity of farmers' socio-demographic variables on their choice of the individual adaptation measures. Finally, quantitative data on factors that constrain farmers' drought adaptation was analysed by using Problem Confrontation Index (PCI).

Key findings

The main findings in line with the specific objectives of the study are summarized as follows.

Regarding the first objective which focused on the spatio-temporal variation in drought for the three study areas for the 1983-2014 climatological year, the following key findings have been noted.

1. It was found that incidence of moderate, severe and extreme droughts was interspersed with moderate and severe wet conditions in all the selected study areas throughout 1983-2014 climatological period.
2. The SPI–defined drought years indicate that prior to 1985, all the selected areas except Busunya experienced extreme drought conditions (SPI = -2.0). Nkoranza North experienced its extreme wet conditions between 1985-1990 whereas its worst extreme drought conditions occurred between 2005-2010 as well as 2010-2014 climatological period (SPI= -2.0 and less).
3. The period from 1983-1995 can be considered as 'prolonged drought years' in Wechaiu as indicated by SPI = -2.0 and less.
4. The 'non-drought' period in Busunya occurred between 1985-1990 as well as between 1995-2000 while Daboase had its 'non-drought' years between 2000-2012. The non-drought' period in Wechaiu occurred between 2000-2006 as well as around 2010
5. Busunya experienced moderately wet as well as moderate drought between 1990-2000 (SPI=+ or -1.0 to 1.49) while Daboase was extremely wet (SPI = 2.0) between 1995-2000.

6. In Wechaiu, wet conditions occurred before and after the years 2005 and 2010 while severe drought (SPI= -1.5) occurred in the middle of 2005 and 2010.
7. With the exception of Wechaiu which experienced severe drought around 2014, non-drought periods lingered in both Daboase and Busunya in 2014.
8. Finally, the survey reveals that most farmers in the three selected agro-ecological locations rated the frequency and severity of drought in the previous years (before 2017) as very high. Most farmers in Daboase and Nkoranza North perceived drought severity in 2017 as moderate while most farmers in Wechaiu in the Wa West in the Savannah agro-ecological zone were of the view that the severity of drought in 2017 was still very high.

With respect to the second specific objective which determined whether there is any significant variation in farmers' vulnerability to drought across the selected agro-ecological locations, the following key findings emerged.

1. Drought imposed very high severe impact on water supply and agricultural activities in the selected agro-ecological locations. Generally, reduction in crop yield, reduction in farm income, increase in food prices, loss of crops and shortage of food were ranked as the first five socio-economic impacts of drought while diseases and insect infestation, and migration were weighted as the two least socio-economic impacts of drought.

2. Moreover, the farmers ranked drying up of surface water, increase in heat wave and deterioration in water quality as the top three environmental impact of drought.
3. Occurrence of bush fires was ranked by the farmers as the least environmental impact of drought.
4. Comparatively, farmers in Wa West District in the Savannah agro-ecological zone have the highest adaptive capacity, followed by farmers in Nkoranza North in the Transitional zone while farmers in Daboase in the Forest zone possess the least adaptive capacity.
5. The study reveals a statistically significant spatial variation between agro-ecological locations and levels of drought vulnerability. Comparatively, farmers in Wa West District in the Savannah zone were highly vulnerable to drought, followed by farmers in Nkoranza North in the Transitional zones. Farmers in Daboase in the Forest zone had the least vulnerability index to drought.

In respect of the third objective of the study which sought to explore farmers' drought adaptation strategies across the agro-ecological locations, it was found that there is a statistically significant difference in farmers' adaptation to drought across the selected agro-ecological locations. The key findings are summarised as follows.

1. It was found that most farmers (72.1%) in the selected study areas adopted application of agro-chemicals as a drought measure. The study shows that the application of agro-chemicals as a drought adaptation measure is significantly associated with agro-ecological location as shown by the χ^2 (2, N = 326) =43.98, $p < .05$). Besides agro-ecological

location, application of agro-chemicals was also significantly determined by years of schooling as well as household size.

2. Moreover, most farmers in Daboase in the Forest zone (91.8%) and Nkoranza North in the Transitional (67.1%) zone did not resort to migration as a drought adaptation measure while most farmers in Wa West District in the Savannah zone (63.2%) employed migration as a drought adaptation measure. The study further revealed that there is a statistically significant relationship between agro-ecological location and farmers' adoption of migration as a drought adaptation measure χ^2 (2, N = 326) =63.0, $p < .05$).
3. The results also point out that most farmers adapted to drought by changing the location of crops. This was significantly determined by agro-ecological location, farm size and access to credit facilities.
4. Most farmers (81.0%) in the three agro-ecological locations adopted the cultivation of early maturing crops as a measure to adapt to drought. The proportion of farmers who employed the cultivation of early maturing crops as drought adaptation measure is significantly different across the three agro-ecological location. Apart from agro-ecological location, the cultivation of early maturing crops was also significantly determined by access to credit.
5. Overall, 50.6% farmers diversified from farm to non-farm income generating activities in order to adapt to the impacts of drought. Majority of farmers (59.2%) who diversified were in Wa West District in the Savannah zone. Agro-ecological location, farming experience,

access to credit, and membership of farm-based association were significant determinants of farmers' diversification intentions.

6. Access to credit facilities and extension services increase the probability of adopting farm-based drought adaptation measures. Farmers with access to credits and extension services are less likely to diversify to non-farming activities.
7. Most farmers (56.4%) integrated livestock production with crop production as drought adaptation measure. However, the proportion of farmers who employed integration of crop and livestock production as drought adaptation measure significantly differ across the three agro-ecological zones. Besides agro-ecological location, it also emerged from the study that access to credit facilities and agricultural extension services could positively and significantly determine farmers' choice of integrating livestock production with crop production as drought adaptation.
8. Finally, most farmers (56.4%) practiced drought monitoring. The adoption of drought monitoring was highly and significantly related to agro-ecological location, χ^2 (2, N = 326) = 27.15, $p < .05$. While 62.7% of the farmers in Daboase in the Forest zone did not practice drought monitoring, it was found that 70.0% and 59.2% farmers in the Nkoranza North and Wa West Districts respectively adopted drought monitoring as a drought adaptation measure. The choice of drought monitoring was also significantly influenced by household size, membership of farm-based association and access to agricultural extension services.

9. Drought adaptation measures such as changing farm size, soil conservation, water harvesting practices and home gardening were not employed by most farmers.

The fourth objective of the study assessed the factors that constrain farmers' adaptation to drought in the selected agro-ecological areas. The key findings comprise the following.

1. It was revealed that shortage of water for irrigation was ranked as the first and foremost factor that served as a constraint to farmers' ability to adapt to drought. A proportion of 85.3% farmers agreed that shortage of water for irrigation constitutes a barrier to drought adaptation.
2. The index ranking also shows that unavailability of financial resources and high cost of agricultural inputs were considered as the second and third constraint to drought adaptation respectively. Majority of 85.3% farmers agreed that unavailability of financial resources served as a constraint to their effort to adapt to drought while 79.8% of farmers indicated that high cost of agricultural inputs served as a barrier to drought adaptation
3. Moreover, inadequate labour force and access to agricultural extension services posed challenge to farmers' quest to adapt to drought.
4. However, inadequate access to weather information, inadequate time for planning and inadequate landholding obtained the least index ranking indicating that these factors did not serve as barriers to farmers' drought adaptation.

Conclusions

The following conclusions were drawn based on the key findings of the study.

With regard to the objective one, periods of moderate, severe and extreme droughts have been interspersed with moderate and severe wet conditions in all the three selected agro-ecological locations throughout 1983-2014. Prior to 1985, all the selected areas except Nkoranza experienced extreme drought conditions. Drought has been more pronounced in Wechaiu compared to Daboase and Nkoranza. Non-drought periods in Nkoranza occurred between 1985-1990 while Wechaiu witnessed extended moments of extreme, severe and moderate drought conditions from 1983-1995. This period can be considered as 'prolonged drought years' in Wechaiu. With the exception of Wechaiu which experienced severe drought around 2014, non-drought periods lingered in both Daboase and Nkoranza in 2014.

Regarding the second objective of the study, it can be concluded that drought imposes adverse impact on farmers and this affects their livelihood activities. Drought vulnerability and rainfall amounts in Ghana shift in the opposite north-south directions. Farmers' vulnerability to drought decreases from north to south while rainfall increases from north to south. This is because drought vulnerability is largely determined by drought exposure and sensitivity. Drought exposure and sensitivity are higher in Wa West District in the Savannah zone compared to the Daboase in Forest and Nkoranza North in the Transitional zone of Ghana. However, farmers in Wa West District possess the highest adaptive capacity. There is a statistically significant spatial variation between agro-ecological locations and levels of vulnerability.

Comparatively, farmers in Wa West District in the Savannah zone were highly vulnerable to drought, followed by farmers in the Nkoranza North District. Farmers in Daboase in the Forest zone had the least vulnerability index to drought.

Furthermore, farmers' adaptation to drought differs across various agro-ecological locations in Ghana and they adapt to drought by employing mixed adaptation strategies. The most commonly used drought adaptation strategies include application of agro-chemicals, changing planting dates, cultivation of different crops, changing location of crops, cultivation of early maturing crops, diversification to non-farm activities, integrating crops and livestock production as well as drought monitoring. Moreover, farmers' choice of specific drought adaptation strategies is a determinant of various factors. Farmers' ecological location acts as the major significant determinant of their adoption of all the eight drought adaptation measures. Finally, farmers with access to credit facilities and extension services are more likely to adopt farm-based drought adaptation measures and less likely to diversify to non-farming activities.

Finally, some farmers have knowledge and experience on drought adaptation. However, there are some bottlenecks that militate against their adaptive capacity and hence, their adoption of drought adaptation strategies. These critical constraints can be prioritized as shortage of water for irrigation, unavailability of financial/credit facilities and high cost of agricultural inputs. Furthermore, inadequate knowledge of drought adaptation as well as inadequate access to agricultural extension officers also pose as constraints to farmers' adaptation to drought.

Recommendations and policy implications

Based on the findings of the study and the conclusions that have been drawn, the following recommendations are made for the purpose of strengthening farmers' adaptive capacity as well reducing their vulnerability to drought. These institutional measures can help reduce or stop human mobility induced by drought especially in the Savannah zone of Ghana.

1. Regarding the inter-annual variability and sporadic nature of drought in Ghana, the government in collaboration with MoFA and GMet should establish agro-information centres in farming communities to provide education on rainfall scenarios to farmers. These centres should be furnished with state-of-the art equipment and the requisite personnel to provide adult education to farmers on rainfall variability, drought episodes, agricultural practices as well as drought adaption technologies. These centres should be resourced to capture relevant information on all rainfall scenarios which will be disseminated to farmers on daily basis. This will enhance farmers' capacity to plan and take advantage of a 'good rainfall periods' within the year.
2. Famers particularly those in the Wa West District in the Savannah zone are more vulnerable to drought. It is therefore recommended that NGOs, MoFA and the National Disaster Management Organization should provide drought relief measures and safety net programmes for vulnerable smallholder farmers. This also calls for the introduction and implementation of crop insurance schemes where farmers would be given the opportunity to indemnify their crops against possible loss associated with drought. There should be safety net programmes that

offer low or interest free agricultural loans, affordable credit facilities, subsidized agricultural inputs, subsidizing food prices during lean season, tanker water supply services, and drought compensation relief to farmers.

3. Colleges and schools of agricultural education in the country to intensify the training of adequate agricultural extension officers to help meet the demands of farmers. These extension officers should be trained on drought adaptation technologies who, upon completion of their education, would heighten drought awareness creation and also educate farmers on how to efficiently adapt to drought conditions.
4. Government in collaboration with the civil society should provide measures aimed at reducing farmers over reliance on rainfall for agriculture production. Private philanthropists should assist the government to construct small-scale pump irrigation facilities and develop alternative water sources for farming communities as a complement to the 'one village, one dam' project.
5. MoFA and National Climate Research Institute should promote the formation of farm-based organisations throughout the country. Farmers should be encouraged to actively participate in these farm-based organisations. This will enhance knowledge sharing and capacity building among group members.
6. As a matter of mitigating farmers' vulnerability to drought, both governmental organizations such as MoFA and National Climate Research Institute, and other non-governmental organisations should help develop, introduce and implement affordable drought adaptation

technologies in farming communities. The introduction and cultivation of drought-resistant crops, water harvesting and conservative agriculture practices should be promoted among farmers in the country.

Suggestions for further research

The scope and limitations of this current study have implications on the results obtained. Therefore, there is the need for further research to be conducted on the following areas.

1. A study should be carried out to assess farmers' vulnerability to drought by using only secondary data on drought exposure, farmers' sensitivity and adaptive capacity throughout all agro-ecological zones in Ghana.
2. Rural participatory approach should be employed to assess farmers' adaptation to drought across the four agro-ecological zones in Ghana.

BIBLIOGRAPHY

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth System Dynamics, 6,* 225-243.

Abdul-Razak, M., & Kruse, S. (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management, 17,* 104-122.

Abraham, J. (2006). *Assessing drought impacts and vulnerabilities for long term planning and mitigation programs*. Doctoral Thesis. University of Arizona, Arizona.

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

Adepetu, A. A., & Berthe, A. (2007). *Vulnerability of rural sahelian households to drought: Options for adaptation. A final report submitted to assessments of impacts and adaptations to climate change* (AIACC), Project No. AF 92. Retrieved from http://www.start.org /Projects/AIACC_Project/Final Reports/Final.

Adesoji, S. A., & Ayinde, J. O. (2013). Ethno-practices and adaptation strategies for the mitigation of climate change by arable crop farmers in Osun State: Implications for extension policy formulation in Nigeria. *Journal of Agricultural and Food Information, 14*(1), 66-76.

Adesoji, S. A., & Famuyiwa, B. S. (2010). *Perception and adaptation to climate change among Fulani cattle rearers in Osun State, Nigeria*. Proceedings of 15th Annual Conference of Agricultural Society of Nigeria, 59-67.

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

African Technology Policy Studies (2013). *Farmers' response and their adaptation strategies to climate change in Mafeteng District, Lesotho*, [Sekaleli T.S.T, Sebusi K.] ATPS Research Paper No. 26.

Agbongiarhuoyi, A. E., Abdulkarim, I. F., Fawole, O. P., Obatolu, B. O., Famuyiwa, B. S., & Oloyede, A. A. (2014). Analysis of farmers' adaptation strategies to climate change in cocoa production in Kwara State. *Journal of Agricultural Extension, 17*(1), 23-40.

Ajzen, I. (1985). From intentions to actions: A theory of planned behaviour. In J. Kuhl & J. Beckmann (Eds.) *Action-control: From cognition to behaviour* (pp. 1 l-39). Heidelberg, Germany: Springer.

Ajzen, I. (1987). Attitudes, traits, and actions: Dispositional prediction of behaviour in personality and social psychology. In: L. Berkowitz (Ed.), *Advances in experimental social psychology* (pp. l-63). New York: Academic Press.

Ajzen, I. (2006). *Theory of planned behaviour*. Retrieved from http://people.umass.edu/~aizen/tpb.diag.htmlnull-link.

Akpoti, K. (2015). *Impact of rainfall variability, land use and land cover change on stream flow for hydropower generation in the Black Volta Basin*. Retrieved from file:///C:/Users /Toshiba /AppData/ Local/Temp /AKP0TI_Thesis.pdf.

Alam, M. O., & Rashid, M. U. (2010). Problem confrontation of coastal youth in undertaking selected agricultural activities in two villages under Bhola District. Bangladesh. *Resource Publication Journal, 4*, 165-171.

Alexander, D. (2012). Models of social vulnerability to disasters. *RCCS Annual Review, 4* (4), 34-50.

AMCEN. (2011). *Drought in the Horn of Africa: Challenges, opportunities and responses*. African Ministerial Conference on the Environment (AMCEN), Fourth Special Session Meeting of the Expert Group, Bamako, 13 and 14 September 2011, Mali.

Amikuzuno, J., & Donkoh, S. A. (2012). *Border effects on spatial price transmission between fresh tomato markets in Ghana and Burkina Faso: Any case for promoting trans-border trade in West Africa?* Paper presented *at* the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil. 18-24 August, 2012.

Amponsem, J. (2015). *Climate change: Drought hits Ghana's second farming season*. Retrieved from www. modernghana.com.

Amusa, T. A., Okoye, C. U., & Enete, A. A. (2015). Gender-based vulnerability and contributions to climate change adaptation decisions among farm households in Southwest Nigeria. *American-Eurasian Journal of Agriculture & Environmental Science, 15* (9), 1779-1789.

Antwi-Agyei, P. (2012). *Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability*. Doctoral Thesis, The University of Leeds School of Earth and Environment.

Antwi-Agyei, P., Fraser, E. D. G., Dougill, A. J., Stringer, L. C., & Simelton, E. (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography*, *32*, 324-334.

Apata, T. G. (2011). Factors influencing the perception and choice of adaptation measures to climate change among farmers in Nigeria. Evidence from farm households in Southwest Nigeria. *Environmental Economics*, *2* (4), 74-83.

Arfanuzzaman, Md, Mamnun, N., Islam, Md S., Dilshad, T., & Syed, Md, A. (2016). Evaluation of adaptation practices in the agriculture sector of Bangladesh: An ecosystem based assessment. *Climate*, *4* (1), 11-20.

Armah, F. A., Odoi, J. O., Yengoh, G. T., Obiri S., Yawson, D. O., & Afrifa, E. K. A. (2011). Food security and climate change in drought-sensitive savannah zones of Ghana. *Mitigation and Adaptation Strategies for Global Change*, *16*(3), 291-306.

Amare, A., & Simane, B. (2018). Does adaptation to climate change and variability provide household food security? Evidence from Muger sub-basin of the upper Blue-Nile, Ethiopia. *Ecological Processes*, *7*, 13.

Amponsem, J. (2015). *Climate change: Drought hits Ghana's second farming season*. Retrieved from www. modernghana.com.

Asafu-Adjaye, N. Y., & Amikuzuno, J. (2015). *The socio-economic impact of climate change adaptation on smallholder farmers in Lawra District, Upper West Region, Ghana.* International Conference on Climate Change and National Development 2015.

Aulong, S., & Kast, R. (2011). *A conceptual framework to assess vulnerability: Application to global change stressors on South Indian farmer*s. Retrieved from http://www.shiva-anr.org.

Avallone, E. A., Baumeister, T., & Sadegh, A. (2007). *Marks' standard handbook for mechanical engineers* (11th ed.). New York: McGraw-Hill Professional.

Baidu, M., Amekudzi, L. K., Aryee, J. N. A., & Annor, T. (2017). Assessment of long-term spatio-temporal rainfall variability over Ghana using wavelet analysis. *Climate*, *5*(2), 5-30.

Balama, C., Augustino, S., Eriksen S., Makonda, F. S. B., & Amanzi, N. (2013). Climate change adaptation strategies by local farmers in Kilombero District, Tanzania. *Ethiopian Journal of Environmental Studies and Management*, *6*(6), 724-736.

Bang, S. K., & Sitango, K. (2003). *Indigenous drought coping strategies and risk management against EL Nino in Papua New Guinea*. The CGPRT Center Working Paper series No. 74, CGPRT, Bogor.

Bawakyillenuo, S., Yaro, J. A., & Teye, J. (2016). Exploring the autonomous adaptation strategies to climate change and climate variability in selected villages in the rural northern savannah zone of Ghana. *Local Environment*, *21* (3), 361-382.

Bekoe, E. O., & Logah, F. Y. (2013). The impact of droughts and climate change on electricity generation in Ghana. *Environmental Sciences, 1*(1), 13 – 24.

Bekoe, E. O., Logah, F. Y., & Kankam-Yeboah, K. (2009). *Evidence of the modification of hydrological cycle in Ghan*a, CSIR WRI/TR No. 178.

Bell, J. (2010). *Doing your research project: A guide for first-time researchers in education, health and social sciences* (5th ed.). New York: McGraw Hill.

Bhattacherjee, A. (2012*). Social science research: Principles, methods, and practices.* Tampa: University of South Florida.

Bhavnani, R., Vordzorgbe, S., Owor, M., & Bousquet, F. (2008). *Report on the status of disaster risk reduction in sub-Saharan Africa Region. Commission of the African Union, United Nations and the World Bank.* Retrieved from http:// www.unisdr.org/files/2229.

Bhttacharyya, D. K. (2012). *Human resource research methods.* Oxford, U. K.: University Press.

Boateng, E. (2015). *Community participation in rural water and sanitation delivery in the Nkoranza North District.* Master's Thesis. Department of Planning, Kwame Nkrumah University of Science and Technology

Bohle, H. G. (2001). Vulnerability and criticality: Perspectives from social geography. *Newsletter of the International Human Dimensions Programme on Global Environmental Change, 3,* 1-7.

Botchway, K. (2016*). Food Security threatened as drought looms.* Retrieved from Citifmonline.com/Ghana.

Bourke, P., Arthur, J., Marshall, N., MacIntyre, J., Wasel, S. M., & Urbaez, E. (2007). *First time disclosure of mineral reserves: Hwini-Butre and Benso properties southwest Ghana* (Technical report). Denver, Colorado, USA: Golden Star Resources Ltd.

Brant, S. (2007). *Assessing vulnerability to drought in Ceará, Northeast Brazil.* Master's thesis, University of Michigan, Michigan.

Bray, N. J., & Williams, L. (2017). A quantitative study on organisational commitment and communication satisfaction of professional staff at a master's institution in the United States. *Journal of Higher Education Policy and Management, 39* (5), 487-502.

British Broadcasting Corporation (2012). *Somali famine: Situation 'still desperate' warns agency.* Retrieved from http://www.bbc.com /news/uk.

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

Bryman, A. (2004). *Social research methods* (2nd ed.). New York: Oxford University Press.

Buckle, P., Mars, G., Smale, S. (2000). New approaches to assessing vulnerability and resilience. *Journal of Management*, *15*, 8-10.

Burke, M., & Lobell, D. (Eds.). (2010). *Food security and adaptation to climate change: What do we know*? Retrieved from http://link.springer.com/book/.

Burney, J., Cesano, D., Russel, J., La Rovere, E. L., Corral, T., Coelha, N. S., & Santos, L. (2014). Climate change adaptation strategies for smallholder farmers in the Brazilian Sertão. *Climatic Change*, *126*(1), *45-59.*

Burton, I., Diringer, E., & Smith, B. (2006). *Adaptation to climate change: International policy options*. Toronto: Pew Centre on Global Climate Change.

Carlton, J. (2014). *California drought will cost $2.2 billion in agriculture losses this year*. Retrieved from http://www.wsj.com/articles/drought.

Cartography, Geographic Information Systems and Remote Sensing Section (2019). Department of Geography and Regional Planning, University of Cape Coast.

Calvo, C., & Dercon, S. (2005). Measuring individual vulnerability. Department of Economics. Discussion Paper Series, 229. Retrieved from http://ideas.repec.org/p/oxf/wpaper/229.html.

Cervantes-Godoy, D., & Dewbre, J. (2010). *Economic importance of agriculture for poverty reduction.* OECD Food, Agriculture and Fisheries Working Papers No. 23, OECD Publishing. Retrieved from https://www.oecd.org/tad/44804637.pdf.

Chhinh, N. (2015). *Drought, drought vulnerability and adaptation policy in Cambodia with reference to the farming sector*. Doctoral thesis, School of Environment, Flinders University of South Australia, Australia.

Ciurean, R. L., Schröter, D., & Glade, T. (2013). *Conceptual frameworks of vulnerability assessments for natural disasters reduction*. Retrieved from http://creativecommons.org/licenses/by/3.0.

Cohen, L., Manion, L., & Morrision, K. (2011). *Research methods in education* (6th ed.). New York: Routledge.

Coleen, V., Laing, M., & Monnik, K. (2006). *A Global assessment*. London: Routledge.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). London: Sage.

Dawson, C. (2007). *A practical guide to research methods* (3rd ed.). Begbroke, Oxford: How to Books Ltd.

Debnath, P., Deb P, Sen D., Pattannaik, S. K., & Ghosh S. K. (2012). Physicochemical properties and its relationship with water holding capacity of cultivated soils along altitudinal gradient in Sikkim. *International Journal Agricultural Environment Biotechnology, 5*(1), 99-104.

Department for International Development (1999). *Sustainable livelihoods guidance sheets*. London, U. K.: Department for International Development.

Deressa, T. T, Hassan, R. M., Ringler, C., Alemu, T., & Yusuf, M. (2008). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change, 19*(2), 248–255.

Devkota, R. P., Cockfield, G., & Maraseni, T. N. (2014). Perceived community-based flood adaptation strategies under climate change in Nepal. *International Journal of Global Warming*, *6,* 113-124.

Di Lena, B., Vergni, L., Antenucci, F., Todisco, F., & Mannocchi, F. (2014). Analysis of drought in the region of Abruzzo (Central Italy) by the Standardized Precipitation. *Theoretical and Applied Climatology, 115*(1/2), 41-45.

Diaz, H. M., & Warren, J. (Eds.). (2016). *Vulnerability and adaptation: The Canadian Prairies and South America* (pp. 16-36). Alberta: University of Calgary Press.

Diaz, H. M., Hurlbert, M., & Warren, J. (2016). *Final research report of the rural communities' adaptation to drought. Regina: Canadian Plains Research Center*. http://www.parc.ca/vacea/assets/PDF/rcadrepor

Dietz, T., van der Geest, K., & Obeng, F. (2013). Local perceptions of development and change in Northern Ghana. In Yaro, J. (Ed.), *Rural development in Northern Ghana* (pp. 17-36). New York: Nova Science Publishers.

Easterling, D. R., Meehl, G. A,, Parmesan, C.,Changnon, S., A., Karl, T. R., & Mearns, L. O. (2000). Climate extremes: Observations, modelling, and impacts. *Science, 289*, 2068-2074.

Edwards, D. C., & McKee, T. B. (1997). Characteristics of 20th century drought in the United States at multiple scales. *Atmospheric Science*, paper no. 634, May 1-30.

Egyir1, I. S., Antwi, G., Ofori, K., Owusu, K., & Ntiamoah- Baidu, Y. (2015). *Implications of climate change for food security among maize producing households around forest protected areas of Ghana*. International Conference on Climate Change and National Development 2015.

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*. Oxford, U. K.: Oxford University Press.

EPA. (2008). *Ghana climate change impacts, vulnerability and adaptation assessments.* Accra, Ghana: Environmental Protection Agency.

Etwire, P. M. (2012). *Assessing the adaptation mechanisms of smallholder farmers to climate change and agro-biodiversity losses in northern Ghana.* Master's Thesis, University of Ghana, Legon.

Etwire P. M., Al-Hassan R. M., Kuwornu J. K. M., & Osei-Owusu Y. (2013). Application of livelihood vulnerability index in assessing vulnerability to climate change and variability in northern Ghana. *Journal of Environment and Earth Science, 3* (2), 201-240.

European Union (2011). *Deliverable D5. Generic conceptual framework for vulnerability measurement*. Retrieved from http://ipcc wg2.gov.

Falola, A., & Achem, B. A. (2017). Perceptions on climate change and adaptation strategies among sweet potato farming households in Kwara State, Northcentral Nigeria. *Ceylon Journal of Science*, *46*(3), 55-63.

Fetterman, D. M. (2008). Key informant. In L. M. Given, (Ed.), *The sage encyclopedia of qualitative research methods* (p. 477). London, U. K.: Sage.

Field, A. (*2009*) *Discovering statistics using SPSS*. (3rd ed.). London, U. K.: Sage.

Fisher, M., Abate, T., Lunduka, R. W., Asnake, W., Alemayehu, Y., & Madulu, R. B., (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climate Change, 133*(2), 283-299.

Flick, U. (2010). *An introduction to qualitative research.* New York: Sage.

Food and Agricultural Organization (2012*). Gender inequalities in rural employment in Ghana: An overview*. Retrieved from http://www.fao.org/docrep/016/ap090e/.pdf.

Forster, P., Jackson L., Lorenz, S., Simelton, E., Fraser, E., & Bahadur, K. (2012). *Food security: Near future projections of the impact of drought in Asia*. Delhi, India: Centre for Low Carbon Futures.

Fosu-Mensah, B.Y., Vlek, P. L. G., & MacCarthy, D. S. (2012). *Farmers' perception and adaptation to climate change: A case study of Sekyeredumase district in Ghana.* Retrieved from http://hdl.handle.net/123456789/1744.

Gaillard, J. C. (2010). Vulnerability, capacity and resilience: Perspectives for climate and development policy. *Journal of International Development, 22*(2), 218-232.

Gallopin, G. C. (2006). Linkages between Vulnerability, Resilience, and Adaptive Capacity. *Global Environmental Change, 16* (3), 235-316.

Gbetibouo, G. A. (2009). *Understanding farmers' perceptions and adaptations to climate change and variability: The Case of the Limpopo Basin, South Africa*; IFPRI Discussion Paper; International Food Policy Research Institute (IFPRI): Washington, DC, USA. Retrieved from http:/www.Ifpri.Org/Sites/blications/Ifpridp00849.Pdf.

Gbetibouo, G. A., Ringler, C., & Hassan, R. (2010). Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resources Forum, 34*(3), 175-187.

Gebrehiwot, T., Veen, A., & Maathuis, B. (2011). Spatial and temporal assessment of drought in the Northern highlands of Ethiopia *International Journal of Applied Observation Geo-information, 13*(3), 309-321.

Ghana Statistical Service (2012). *2010 Population and housing census. Summary report of* final *results. Ghana*, Accra: Ghana Statistical Service.

Ghana Statistical Service (2013). *2010 Population and housing census: Regional analytical reports-Upper West Region*. Ghana, Accra: Ghana Statistical Service.

Ghana Statistical Service (2013). *Ghana living standard survey*. *Ghana*, Accra: Ghana Statistical Service.

Ghana Statistical Service (2014). *2010 Population and housing census: Regional analytical reports-Upper West Region. Ghana*, Accra: Ghana Statistical Service.

Ghana Statistical Service (2014). *2010 Population and housing census: District analytical report. Nkoranza North.* Accra: Ghana Statistical Service.

Ghana Statistical Service (2014). *2010 Population and housing Census. District analytical report. Wassa East.* Accra: Ghana Statistical Service.

GMet (1998-2016). *Climatology*. Retrieved from http://www.meteo.gov.gh.

Golo, B. K., & Yaro, J. A. (2013). Reclaiming stewardship in Ghana: Religion and climate change. *Nature and Culture*, *8*(3), 282-300.

Government of Ghana (2013). *The 2013 Budget statement and economic policy*. Accra, Ghana Ministry of Finance and Economic Planning.

Greene, W. H. (2003). *Econometric analysis. (*5th ed). Upper Saddle River, New York: Prentice Hall.

Greene, W. H. (2007). *LIMDEP version 9.0 econometric modelling guide*. Plainview, New York: Econometric Software.

Gyau-Boakye, P., & Tumbulto, J. W. (2000). The Volta Lake and declining rainfall and streamflows in the Volta River Basin. *Environment, Development and Sustainability, 2,* 1-10.

Harley, M., Horrocks, L., Hodgson, N., & van Minnen, J. (2008). *Climate change vulnerability and adaptation indicators.* European Topic Centre on Air and Climate Change Technical Paper 2008/9, European Environment Agency.

Harvey, C. A., Rakotobe, L., Rao, N. S., Dave, R., Razafimahatratra, H., Hasinandrianina, R., Rajaofara, H., & Mackinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society*. Retrieved from http://dx.doi.org.

Hassan, R., & Nhemachena, C. (2008). Determinants of climate adaptation strategies of African farmers: Multinomial choice analysis, *African Journal of Agricultural and Resource Economics*, *2*(1), 83-104.

Hayes, M., Svoboda, M., Wall N., & Widhalm, M. (2011). The Lincoln declaration on drought indices: Universal meteorological drought index recommended. *Bulletin of the American Meteorological Society, 92*, 485-488.

Hill, M., & Engle, N. L. (2013). Adaptive capacity: Tensions across scales. *Environmental Policy and Governance, 23*(3), 177-192.

Hisdal, H., & Tallaksen, L.M. (Eds.). (2000). *Drought event definition*. Technical Report 6 of the ARIDE Project, Assessment of the Regional Impact of Droughts in Europe, Department of Geophysics, University of Oslo, Norway.

Hossain, M. S., & Miah, M. A. M. (2011). Poor farmers' problem confrontation in using manure towards integrated plant nutrition system. *Bangladesh Journal of Extension Education, 23* (1&2), 139-147.

Intergovernmental Panel on Climate Change (2001). *Climate Change 2001 Summary for Policy makers, A contribution of Working Group I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: University Press.

Intergovernmental Panel on Climate Change (2007). *Summary for policymakers in climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change (2013). *Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report*. Cambridge, United Kingdom: Cambridge University Press.

Intergovernmental Panel on Climate Change (2014). *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Isham, J. (2002). The effect of social capital on fertilizer adoption: Evidence from rural Tanzania. *Journal of African Economies*, *11*, 39-60

Jackson, S. L. (2011). *Research methods and statistics: A critical thinking approach* (3rd ed.). Singapore: Cengage Learning.

Jakpa, J. T. (2015). *Smallholder farmers' vulnerability to floods in the Tolon District, Ghana.* Master's thesis. Accra: University of Ghana.

Jawura, F. X. (2013). *Drought and migration in Northern Ghana*. Doctoral Thesis, University of Ghana, Legon.

Jawura, F. X. (2014). Perceptions of drought among rural farmers in the Savelugu district in the northern Savannah of Ghana. *Ghana Journal of Geography*, *6*, 102-120.

Johnson, K. M., & Brell, M. (2012). *Conceptualizing urban adaptation to climate change. Findings from an applied adaptation assessment framework*. Research papers. Retrieved from http://www.cmcc.it /wp-content /uploads /2012/06 /rp0131-cip-03-2012.pd.

Kankam-Yeboah, K., Obuobie,E., Amisigo, B., & Opoku-Ankomah, Y. (2013). Impact of climate change on streamflow in selected river basins in Ghana. *Hydrological Sciences Journal*, *58* (4), 773-788.

Kelly, P. M., & Adger, W. N. (2000). Assessing vulnerability to climate change and facilitating adaptation. *Climatic Change, 47*, 325-352.

Kloos, J., & Renaud, F. G. (2014). Organic cotton production as an adaptation option in North West Benin. *Outlook on Agriculture, 43*(2), 91-100.

Kumar, R. (2011). *Research methodology: A step by step guide for beginners* (3rd ed.). New Delhi: Sage Publishers.

Kurothe, R. S, Kumar G., & Singh, R. (2014). Effect of tillage and cropping systems on runoff, soil loss and crop yields under semiarid rain fed agriculture in India. *Soil Tillage Reserve, 140*, 126-34.

Lacombe, G., McCartney, M., & Forkuor, G. (2012). Drying climate in Ghana over the period 19602005: Evidence from the resampling-based Mann-Kendall test at local and regional levels. *Hydrological Sciences Journal, 57*(8), 1594-1609. Retrieved from http://www.tandfonline.com /doi /abs/ 101080 /02626667. 2012.728.

Laube, W., Awo, M., & Schraven, B. (2008). *Erratic rains and erratic Markets: Environmental change, economic globalisation and the expansion of shallow groundwater irrigation in West Africa*. ZEF Working Paper Series, No. 30. Bonn.

Laux, P. (2010). Impact of climate change on agricultural productivity under rainfed conditions in Cameroon. A method to improve attainable crop yields by planting date adaptations. *Agricultural and Forest Meteorology*. Retrieved from www.j.agrformet.

Levina, E., & Tirpack, D. (2006). *Adaptation to climate change: Key terms Organisation for Economic Co-Operation and Development*. Retrieved from http://www.Oecd. Org/Pdf.

Lin, Y., Deng, X., and Jin, Q. (2013). Economic effects of drought on agriculture in North China. *International Journal of Disaster Risk Science, 4*(2), 59-67.

Logah, F. Y., Obuobi, E., Ofori, D., Kankam-Yeboah, K. (2014). Analysis of rainfall variability in Ghana. *International Journal of Latest Research in Engineering and Computing, 1*(1), 1-8.

Lorenzo-Lacruz, J., & Moran-Tejeda, E. (2016). Spatio-temporal patterns of meteorological drought in the Balearic Islands (Spain). *Cuadernos de Investigacion Geografica, 42*(10), 49-66.

Luni, P., Maharjan, K. L., Joshi, N. P. (2012). Perceptions and realities of climate change among the Chepong Communities in rural mid-hills of Nepal. *Journal of Contemporary India Studies, 2*, 35-50.

Luwesi, C. N., Obando, J. A., C. A., & Shisanya, B. (2017). The impact of a warming micro-climate on Muooni farmers of Kenya. *Agriculture, 7*, 20-25.

Mabe, F. N., Sienso, G., & Donkoh, S. (2014). Determinants of choice of climate change adaptation strategies in Northern Ghana. *Research in Applied Economics, 6*(4), 75-94.

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

Makoka, D. (2008). *The impact of drought on household vulnerability: The case of rural Malawi.* Paper Presented at the 2008 United Nations University (UNU-EHS) Summer Academy on Environmental Change, Migration and Social Vulnerability. Retrieved from http://mpra.ub.uni-muenchen.de/15399.

Maliva, R., & Missimer, T. (2012). Aridity and drought. *Arid Lands Water Evaluation and Management*, *2*(4), 21-39.

Manyena, S. B. (2006). The concept of resilience revisited. *Disasters*, *30*(4), 434-450.

Matthews, R., & Sydneysmith, R. (2010). Climate change and institutional capacity in an "arctic city: A CAVIAR case study of Whitehorse. In: Hovelsrud, G.K. & Smit, B. (Eds.) *Caviar: Community adaptation and vulnerability in arctic regions.* (pp. 239-261). New York: Springer Science and Business Media.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (2001). *Climate Change 2001: Impacts, adaptation and vulnerability*. Cambridge: Cambridge University Press.

McEntire, D. (2004). Triggering agents, vulnerability and disaster reduction, towards a holistic paradigm. *Disaster Prevention and Mitigation, 10* (3), 189-196.

McKee, B. T., Doesken, J. N., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales, Proceedings of ninth Conference on Applied Climatology. *American Meteorological Society, Boston*, 179-184.

McSweeney, C., New, M., & Lizcano, G., (2012). *UNDP Climate change country Profiles, Ghana*. Retrieved from http://www.countryprofiles.geog.ox.ac.uk.

Mensah-Bonsu A., Sarpong, D. B., Al-Hassan R, Asuming-Brempong S, Egyir I., Kuwornu J., & Osei-Asare, Y. (2011). *Technology adoption and land and water management practices among maize farmers in Ghana.* Retrieved from http://addis2011.ifpri.info/files/2011/10/Paper.

Mishra, A. K., & Singh, V. P. (2010). A review of drought concept. *Journal of Hydrology, 391*, 202-216.

Moench, M., & A. Dixit (Eds.). (2007). *Working with the winds of change. toward strategies for responding to the risks associated with climate change and other hazards.* ProVention Consortium (2nd ed.). Nepal: Institute for Social and Environmental Transition-International; Institute for Social and Environmental Transition.

Montle, B. P., & Teweldemedhin, M.Y. (2014). Assessment of farmers' perceptions and the economic impact of climate change in Namibia: Case study on small-scale irrigation farmers (SSIFs) of Ndonga Linena Irrigation Project. *Journal of Development and Agricultural Economics, 6*, 443-454.

Moret, W. (2014). *Vulnerability assessment methodologies: A review of the literature.* Retrieved from https://www.fhi360.org /sites /default /files/media /documents.

Moser, S.C. & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences, 107*(51), 22026-22031.

Nabikolo, D., Bashaasha, B., Mangheni, M. N., & Majaliwa, J. G. M. (2012). Determinants of climate change adaptation among male and female headed farm households in eastern Uganda. *African Crop Science Journal, 20*(2), 203-212.

NASA. (2007). *Long-term increase in rainfall seen in tropics*. Retrieved from https://www.nasa.gov/centers/goddard/news/topstory/2007/rainfall.

Ndamani, F., & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola, 73*(3, 201-208.

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., & Howden, S. M. (2010). The Vulnerability of Australian rural communities to climate variability and change: Part II-integrating impacts with adaptive capacity. *Environmental Science and Policy, 13*, 18-27.

Nhemachena, C., & Hassan, R. H. (2007). *Micro-level analysis of farmers' adaptation to climate change in southern Africa*. IFPRI Discussion Paper No. 00714; International Food Policy Research Institute: Washington, DC, USA, 2007. Retrieved from http://ageconsearch.umn.edu/handle/42399.

Nkoranza North District Assembly (2016). *The composite budget of Nkoranza North District Assembly for the 2016 fiscal year*. Retrieved from https://www.mofep.gov.gh/sites/default/files/composite-budget/2016/BA/Nkoranza-North.pdf.

Nkrumah, F., Klutse, N. A. B., Adukpo, D.C., Owusu, K., Quagraine, K.A., Owusu, A., & Gutowski, W., Jr. (2014). Rainfall Variability over Ghana: Model versus Rain Gauge Observation. *International Journal of Geosciences, 5,* 673.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology, 41* (1/2), 127-150.

Nyadzi, E. (2016). Climate Variability Since 1970 and Farmers' Observations in Northern Ghana. *Sustainable Agriculture Research, 5*(2), 41-56.

Obayelu, O. A., Adepoju, A. O., & Idowu, T. (2014). Factors influencing farmers' choices of adaptation to climate change in Ekiti State, Nigeria**.** *Journal of Agriculture and Environment for International Development, 108* (1), 3-16.

O'Brien, K., Eriksen, S., Schjolden, A., & Nygaard, L. (2004). *What's in a word? Conflicting interpretations of vulnerability in climate change research.* CICERO: Centre for International Climate and Environmental Research.

O'Brien, K., Eriksen, S., Schjolden, A., & Nygaard, L. (2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, *7*, 73-88.

Oliver-Smith, A. (2004). Theorizing vulnerability in a globalized world: A political ecological perspective. In G. Bankoff, G. Frerks, & D. Hilhorst (Eds.), *Mapping vulnerability: Disasters, development & people* (pp. 10-24). London: Earthscan.

Ogalleh, S. A., Vogl, C. R., Eitzinger, J., & Hauser, M. (2012). Local perceptions and responses to climate change and variability: The Case of Laikipia District, Kenya. *Sustainability*. Retrieved from www.mdpi.com/journal/sustainability.

Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., & Munang, R. (2015). Drought adaptation and coping strategies among the Turkana Pastoralists of Northern Kenya. *International Journal of Disaster Risk Science, 6,* 295–309. Retrieved from www.ijdrs.com.

Osei-Owusu, Y., Al-Hassan, R. M., & Doku-Marfo, E. (2012). Assessing the adaptation mechanisms of smallholder farmers to climate change and agrobiodiversity losses in northern Ghana. *Journal of Environment and Earth Science, 4* (4), 20-37.

Osuala, E. C. (2001). *Introduction to research methodology* (3rd ed.). Nigeria, Onistsha: Africana-FEP Publishers Ltd.

Owusu, K. (2009). *Changing rainfall climatology of west Africa: Implications for rainfed agriculture in Ghana and water sharing in the Volta Basin.* Doctoral dissertation. Florida: University of Florida.

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

Pardoe, J., Kloos, J., & Assogba, N. P. (2016). Seasonal Variability: Impacts, Adaptations and the Sustainability Challenge. In Yaro, J. A., & Hesselberg, J., (Eds.), *Adaptation to climate change and variability in rural West Africa*, (pp. 41-57). Switzerland: Springer International Publishing.

Park, M. H. (2010). *Regression models for binary dependent variables using Stata, SAS, R, LIMDEP, and SPSS*. Working paper. The University Information Technology Services (UITS) Centre for Statistical and Mathematical Computing, Indiana University. Retrieved from http://www.indiana.edu /~statmath/stat/all/cdvm/index.html.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Polthanee, A., Promkhumbut, A., & Bamrungrai, J. (2014). Drought impact on rice production and farmers' adaptation strategies in Northeast Thailand. *International Journal of Environmental and Rural Development*, *5*(1), 45-52.

Parsons, J. A. (2008). Key informant. In P. J. Lavrakas, (Ed.), *Encyclopaedia of survey research methods* (p. 407). London: Sage Publications, Inc.

Quagraine, K. A., Klutse, N. A. B., Nkrumah, F., Adukpo, D. C., & Owusu, K. (2017). *Changes in rainfall characteristics in Wenchi and Saltpond farming areas of Ghana*. Retrieved from http://ugspace.ug.edu.gh/handle.

Quandt, A., & Kimathi, Y. A. (2016). Adapting livelihoods to floods and droughts in arid Kenya: Local perspectives and insights. *African Journal of Rural Development*, *1*(1), 51 – 60.

Rahman, M. Z., Yamao, M.,& Alam, M. A. (2007). Barriers faced by small farmers in adopting the integrated plant nutrient system for sustainable farming development. *Sabaragamuwa University Journal*, *7* (1), 3-21.

Rodima-Taylor, D., Olwig, M. F., & Chhetri, N., (2012). Adaptation as innovation, innovation as adaptation: An institutional approach to climate change. *Applied Geography, 33,* 107-111.

Roy, D., Farouque, M. G., & Rahma, M. Z., (2013). Problem confrontation of the FFS farmers in participating in farmer field school training session progress. *Agriculture, 24* (1 & 2), 273-28.

Schilling, J., & Remling, E. (2011). *Local adaptation and national climate change policy in Kenya: Discrepancies, options, and the way forward.* Universitat Hamburg, Research Group Climate Change and Security (CLISEC), Germany.

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

Sheffield J., & Wood, E. (2011). *Drought: Past problems and future scenarios*. London: Earthscan.

Shiferaw, B., Tesfaye, K., Kassie, M., & Abate, T. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather and Climate Extremes, 3*(4), 67-79. Retrieved from www.elsevier.com/locate/wace.

Shitangsu, K. P. (2013). Vulnerability concepts and its application in various fields: A review on geographical perspective. *Journal of Life Earth Science, 8,* 63-81. Retrieved from http://banglajol.info.index.php/JLES.

Shongwe, P., Masuku, M. B., & Manyatsi, A. B. (2014). Factors influencing the choice of climate change adaptation strategies by households: A case of Mpolonjeni Area Development Programme (ADP) in Swaziland. *Journal of Agricultural Studies, 2*(1), 86-98.

Sienso, G., Asuming-Brempong, S., & Amegashie, D. P. K. (2013). *Estimating the efficiency of maize farmers in Ghana*. Contributed Paper prepared for presentation at the 4th International Conference of the AAAE, Cape Town, Hammamet, Tunisia, 22 - 25 September, 2013.

Simpson, M. C., Gössling, S., Scott, D., Hall, C. M., & Gladin, E. (2008). *Climate change adaptation and mitigation in the tourism sector: Frameworks, tools and practices.* Retrieved from http://wedocs.unep.org/bitstream/Climate-Change-adaptation.

Sivakumar, M. V. K., Motha, R. P., Wilhite, D. A., & Wood, D. A. (2011). *Agricultural drought indices. Proceedings of an expert meeting in Spain*. Retrieved from www.droughtmanagement MO_ agricultural_ drought_indices. pdf.

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

Soanes, C., & Stevenson, A. (Eds.). (2005). Oxford dictionary of English (2nd ed.). Oxford: University Press.

Speranza, C. I. (2010). Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni District, Kenya. *European Journal of Development Research 22*(5), 623-642.

Stanturf, J. A., Warren, M. L., Charnley, Jr. S., Polasky, S. C., Goodrick, S. L., Armah, F., & Nyako, Y. A. (2011). *Ghana climate change vulnerability and adaptation assessment*. Washington: US Agency for International Development.

Sun, F., Roderick, M., & Farquhar, G. A. (2012). Changes in the variability of global land precipitation. *Geophysical Research Letters, 39* (19), 12-32.

Svendsen, S., M. Ewing, K., & Msangi, S. (2009). *Measuring irrigation performance in Africa*. IFPRI Discussion Paper 894. Washington, D.C.: International Food Policy Research Institute.

Swain, M., & Swain, M. (2011). Vulnerability to Agricultural Drought in Western Orissa: A Case Study of Representative Blocks. *Agricultural Economics Research Review, 24,* 47-56.

Tesso, G., Emana, B., & Ketema, M. (2012). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. *Agricultural Sciences, l3* (6), 871-888.

Thomas, J. C. (2007). *Administrative, faculty, and staff perceptions of organisational climate and commitment in Christian higher education (Ph.D., Capella University).* ProQuest Dissertations and Theses. Retrieved from http://search.proquest.com/docview/304699607.

Thornton, T. F., & Comberti, C. (2013). Synergies and trade-offs between adaptation, mitigation and development. *Climate Change*, 1-14. Retrieved from http://link.springer.com/article/10.1007/s10584-013-0884-3.

Tilahun, K. (2006). Analysis of rainfall climate and evapotranspiration in arid and semi-arid regions of Ethiopia using data over the last half a century. *Journal of Arid Environments, 64*, 74-87.

Turner, B. S., & Dumas, A. (2013). Vulnerability, diversity and scarcity: On universal rights. *Medicine, Health Care and Philosophy*, 16 (4), 663-670.

Uddin, M. N., Bokelmann, W., & Entsminger, J. S. (2014). Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects:A Farm Level Study in Bangladesh. *Climate, 2*, 223-241.

Udmale, P., Ichikawa, Y., Manandhar, S., Shidaira, H., & Kiem, A. S. (2014). Farmers' perception of drought impacts, local adaptation and administrative mitigation measures in Maharashtra State, India. *International Journal of Disaster Risk Reduction, 10*, 250-269.

UNESCO. (2007). *Disaster preparedness and mitigation.* France, Paris: UNESCO.

UNFCCC. (2007). *Climate change: Impacts, vulnerabilities and adaptation in developing countries*. Retrieved from www.unfccc.int.

UNFCCC. (2011). *Assessing climate change impacts and vulnerability: Making informed adaptation decisions*. Retrieved from www.unfccc.int/adaptation.

United Nations (2010). *Natural hazards, unnatural disasters: The economics of effective prevention.* Washington, D.C.: World Bank.

Van de Giesen, K., Liebe J, Jung, G. (2010). Adapting to climate change in the Volta Basin, West Africa. *Current Science*, 98(8), 1033-1037.

Van der Geest, K. (2004). *We're managing! Climate change and livelihood vulnerability in Northwest Ghana*. Leiden: African Studies Centre

Van der Geest, K. (2011). *The Dagara farmer at home and away. Migration, environment and development in Ghana*. PhD Dissertation, University of Amsterdam. Leiden: African Studies Centre.

Wa West District Assembly (2012). Retrieved from https://wawebstdistrictassembly.wordpress.com/home.

Wandel, J., Diaz, H., Warren, J., Hadarits, M., Hurlbert, M., & Pittman, J. (2016). Drought and vulnerability: A conceptual approach. In H. Diaz, Hurlbert,M., & J. Warren (Eds.). *Vulnerability and adaptation: The Canadian Prairies and South America* (pp. 16-36). Alberta: University of Calgary Press.

Wani, S. A., & Chand, S. (2013). Organic farming: As a climate change adaptation and mitigation strategy. *Scholarly Journal of Agricultural Science, 3*(8), 294-298.

Wassa East District (2016). *Drought hit Daboase in 2016*. Retrieved from https://www.graphic.com.gh/features/features/and-the-taps, 2016).

Wassa East District Assembly (2015). *The composite budget of Wassa East District Assembly for the 2015 fiscal year*. Daboase, Ghana: Wassa East District Assembly.

Wassa East District Assembly (2016). *The composite budget of Wassa East District Assembly for the 2016 fiscal year*. Daboase, Ghana: Wassa East District Assembly.

Washington State Department of Agriculture (2015). *Interim Report: 2015 drought and agriculture. A Study by the Washington State Department of Agriculture.* Retrieved from http://agr.wa.gov /FP/Pubs /Natural ResourcesAssessmentPubs.aspx.

Water Resources Commission (2010). *Climate change, water and diseases. Perspectives from Ghana's three Northern Regions of Ghana*. Water Resources Commission, WRC-CCA Report Series No. 1.

Wilhite D. A. (2000). *Drought as a natural hazard: Concepts and definitions. Drought: a global assessment.* London, U. K.: Routledge Publishers.

Wilhite, D.A., & Glantz, M. H. (1985). Understanding the drought phenomenon: The role of definition. *Water International*, *10*, 111-120.

Wilhite, D.A., & Buchanan-Smith, M. (2005). Drought as a Natural Hazard: Understanding the Natural and Social Context. In D. A. Wilhite (Ed.), *Drought and Water Crises: Science, Technology, and Management Issues* (pp. 3-29). New York: Taylor and Francis.

Wilhite, D. A. (2011). *Quantification of agricultural drought for effective drought mitigation and preparedness: Key issues and challenges.* Drought Mitigation Centre Faculty Publications. 82. Retrieved from http://digitalcommons.unl.edu/droughtfacpub/82.

Wisconsin Initiative on Climate Change Impacts [WICCI]. (2011). *Wisconsin changing climate: Impacts and adaptation.* Retrieved from www.wicci.wisc.edu

Wisner, B., Blaikie, P., Cannon, T., & Davis, *I.* (2003). *At Risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). New York: Longman Group.

Wolf, S., Lincke, D., Hinkel, J., Ionescu, C., & Bisaro, S. (2008). Formal framework of vulnerability final deliverable to the Adam project. FAVAIA Working Paper 8. Retrieved from www.pik-potsdam.de/favaia.

World Bank (2010). *Natural disaster risk management in the Philippines: Enhancing poverty alleviation through disaster reduction.* Retrieved from http://openknowledge.worldbank.

WMO. (2005). *Drought assessment and forecasting*. Retrieved from http://www.wmo.int/pages/prog/hwrp/documents/regions/DOC8.pdf.

WMO. (2006). *Drought monitoring and early warning: Concepts, progress and future challenges.* WMO No. 1006. Geneva: WMO.

WMO. (2012). *The Standardized Precipitation Index user guide.* Geneva: WMO.

WMO & GWP. (2016). Handbook of drought indicators and indices. Integrated drought management tools and guidelines Series 2. Geneva: WMO.

Yamane, T. (1967). *Statistics: An Introductory Analysis* (2nd.). New York: Harper and Row.

Yang, J., Tan, C., Wang, S., Wang, S., Yang, Y., & Chen, H. (2015). Drought adaptation in the Ningxia Hui Autonomous Region, China: Actions, planning, pathways and barriers. *Sustainability*, 7, 15029-15056.

Yaro, Y. A. (2012). *Building resilience and reducing vulnerability to climate change: Implications for food security in Ghana.* Retrieved from library.fes.de/pdf-files/bueros/ghana/10517.pdf.

Yaro, J. A. (2013). The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change*, *13*, 1259-1272.

Yaro, Y. A., & Hasselberg, J. (Eds.). (2016). *Adaptation to climate change and variability in rural West Africa*. Switzerland: Springer International Publishers.

Yin, R. K. (2013). *Case study research: Design and methods*. London, U. K.: Sage Publications.

Yiran, G. A. B., & Lindsay, S. C. 2016). Spatio-temporal analyses of impacts of multiple climatic hazards in a savannah ecosystem of Ghana. *Climate Risk Management*, *14*, 11-26.

You, L. Z. (2010). *What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach*. International Food Policy Research Institute. Retrieved from https://www.google.com/search?

Yuga, N. G., Shivakoti, P. G., & Sylvain, R. P. (2010). Household-level vulnerability to drought in Hill Agriculture of Nepal: Implication for adaptation planning. *International Journal of Sustainable Development and World Ecology*, *17*(3), 225-230.

Zakour, M. J. (2010). Vulnerability and risk assessment: Building community resilience. In D. F. Gillespie & K. Danso (Eds.), *Disaster concepts and issues: A guide for social work education and practice* (pp. 15-60). Alexandria, Egypt: Council on Social Work Education.

Zakour, M. J., & Gillespie, D. F. (2013). *Community disaster vulnerability: Theory, research and practice*. New York: Springer Science.

Zamani, G. H., Zarafshani, K., & Gorgievski-Duijvesteijn M. (2006). A multidisciplinary approach to facilitate change in farmers' psychological coping strategies when dealing with adversities: A case study in Southwest in Iran. In Connors J. J. (Ed.), *Conference Proceedings of the 21st Annual Conference of Association for International Agricultural and Extension Education* AIAEE, Educational, Extension and Research Strategies for a Changing World (pp 484–493). San Antonio, Texas, USA: AIAEE.

Zarafshani, K., Zamani G. H., & Gorgievski-Duijvesteijn, M. J. (2005). Perceptions and psychological coping strategies of farmers toward drought: implications for extension professionals. *Journal of Extension Systems, 1*(21), 58-71.

Zarafshani, K., Sharafi, L., Azadi, H., Hosseininia, G.H., De Maeyer, P., & Witlox, F. (2012). Drought Vulnerability Assessment: The Case of Wheat Farmers in Western Iran. *Global and Planetary Change*, *98/99*, 122-130.

Zarafshani, K., Sharafi, L., Azadi, H., & van Passel, S. (2016). Vulnerability assessment models to drought: Toward a conceptual framework. *Sustainability*, 8, 588.

Zargar, A., Sadiq, R., Naser, B., & Khan, F. I. (2011). A review of drought indices. *Environmental Review*, *19*, 333–349.

Ziolkowska, J. R. (2016). Socio-economic implications of drought in the agricultural sector and the state economy. *Economies, 4*, **(**9), 19-30.

Žurovec, O., Cadro, S., & Sitaula, B. K. (2017). Quantitative assessment of vulnerability to climate change in rural municipalities of Bosnia and Herzegovina. *Sustainability*. Retrieved from www.mdpi.com /journal/sustainability.

APPENDICES

A: DROUGHT VULNERABILITY AND ADAPTATION SURVEY QUESTIONNAIRE

Dear Participant,

This study is being conducted on the topic: "Farmers' Vulnerability and Adaptation to Drought in Wa West, Nkoranza North and Wassa East Districts, Ghana". Please, it is an academic exercise which aims at soliciting your views and responses with regard to how vulnerable you are to drought impact. The study further seeks to investigate the long-term measures that you adopt to combat drought. Finally, it will elicit your views on factors that constrain your capacity to adopt drought adaptation strategies.

The questionnaire is structured into sections A, B, C, D and E. You are expected to tick [√] in the appropriate space to reflect your judgment on each statement. For others you may write on the space provided.

You are kindly requested to assist me with the needed information for the success of this study. Your responses and identity shall be treated with the utmost confidentiality. Please, try as much as possible to be frank with your responses.

Your participation in this exercise is voluntary. If you participate, it will take you about 30 minutes to fill this questionnaire.

Feel free to talk to me personally or contact me through Tel: +233-247658789 or email: hillary.dumba@ucc.edu.gh Thank you very much for your cooperation and participation in this brief exercise.

SECTION A: SOCIO-DEMOGRAPHIC DATA OF RESPONDENTS

1. Name of community………………………………..
2. Gender: Male [ ] Female [ ]
3. Age : ………………….
4. Marital status: Single [ ] Married [ ] Divorced [ ] Separated [ ]
5. Highest level of formal education: No education [ ] Primary education [ ] Junior High education [ ] Middle school education [ ] Secondary school education [ ] Post-secondary education [ ]
6. Years of schooling………………………...
7. Size of crop farm: …………………………
8. Household size……………………………………..
9. What is the size of your landholding? ....
10. Number of dependents …………….

SECTION B: FARMERS' EXPOSURE TO DROUGHT

Please tick [√] in the spaces provided to rate your perceived exposure to drought by using the scale: 4= very high, 3= high, 2= moderate and 1=low.

11. To what extent will you rate the severity of drought in the past years?

    Low [ ] Moderate [ ] High [ ] Very High [ ]

12. To what extent will you rate the severity of drought during this year?

    Low [ ] Moderate [ ] High [ ] Very High [ ]

13. To what extent will you rate the frequency of occurrence of drought in the past years? Low [ ] Moderate [ ] High [ ] Very High [ ]
14. How will you rate the severity of drought impact on water supply?

    Low [ ] Moderate [ ] High [ ] Very High [ ]

15. How will you rate the severity of drought impact on agricultural use?

Low [ ] Moderate [ ] High [ ] Very High [ ]

16. To what extent will you rate the frequency of drought during this year?

Low [ ] Moderate [ ] High [ ] Very High [ ]

SECTION C: DROUGHT SENSITIVITY

Please tick [√] in the spaces provided to indicate your level of vulnerability to the following social, economic and environmental impacts imposed by drought by using the scale: **High =3; Moderate = 2; Less =1 and Not at all = 0**

No.	Social Indicators	High	Moderate	Less	Not at all
17	Migration of people to other places				
18.	Shortage of food				
19.	Conflict over water				
20.	Sense of hopelessness				
21.	Drop out of children from school				
22.	Health impact (diseases and insect Infestation				
23	Disruption of festival celebration				
	Economic indicators				
24.	Increased in food prices				
25.	Loss of livelihood activities				
26.	Loss of crops				
27	Reduction in crop yield				
28.	Decrease of livestock				
29	Indebtedness				
30.	Reduction in farm income				
31.	Increased in livestock diseases				
	Environmental indicators				

32.	Drying up of surface water (streams, rivers, ponds, dams etc)				
33.	Decline in groundwater levels				
34.	Increase in average heat and temperature				
35.	Reduction in soil moisture				
36.	Deterioration of water quality				
37.	Destruction of vegetation				
38.	Damage to wildlife				
39.	Reduction in soil fertility				
40	Occurrence of bush fires				
41	Inadequate access to water				

SECTION D: FARMERS' ADAPTIVE CAPACITY

No.	**Statement**	Yes	No
42	Do you have access to credit facilities?		
43	Do you own a TV?		
44	Do you own radio?		
45	Do you possess mobile phone?		
46	Do you have landholding?		
47	Have you obtained formal education/training?		
48	Do you farm around wetland?		
49	Do you own livestock?		
50	Do you have access to irrigation facility?		
51	Do you have access to water pump?		
52	Do you receive remittance?		
53	Are you a member of a farming-based association?		
54	Are you a member of saving and credit institutions?		
55	Do you have access to mutual fund ('susu')?		
56	Do you have access to rainfall warning information?		
57	Do you own perennial cash plants?		
58	Do you have access to agricultural extension services?		

59	Do you have knowledge of new farming practices (e.g farming methods, farm inputs, improved seed varieties etc.)?		
60	Do you get access to agricultural inputs (e.g chemicals, farm implements, improved seeds etc)?		
61	Do own a spraying machine?		
62	Do you get off-farm income (trading, construction work, etc)?		

SECTION E: DROUGHT ADAPTATION STRATEGIES

Please tick [√] in the appropriate spaces provided to indicate whether you have adopted each of these drought adaptation strategies or not.

No.	Adaptation strategy	Adopted	Not adopted
63	Application of agro-chemicals		
64.	Changed timing of crop planting		
65.	Cultivation of different crops on the same farmland		
66.	changed location of crop fields		
67.	Adoption of irrigation system		
68	Migration		
69.	Use of soil moisture conservation techniques		
70	Cultivation of drought tolerant crop varieties		
71	Cultivation of early maturing crops		
72	Diversifying from farm to non-farm income activities		
73	Integrating cultivation of crops with livestock production		
74	Home gardening		
75	Use of water harvesting practices		
76	Changing the size of farm lands		
77	Buy crop insurance		
78	Improved drought monitoring		

SECTION F: CONSTRAINTS TO FARMERS' ADAPTATION TO DROUGHT

Please, tick [√] in the appropriate box to indicate the extent of your agreement or disagreement with the following statements as factors that constrain your capacity to adapt to drought by using the key: **SD = Strongly Disagree; D = Disagree; NS= neither agree nor disagree; A = Agree; and SA = Strongly Agree.**

No.	**Constraints to drought adaptation** Preamble: I am constrained to adapt to drought because of:	SD	D	NS	A	SA
79	inadequate access to weather information					
80	inadequate knowledge on how to adapt to drought					
81	unavailability of financial resources					
82	high cost of agricultural inputs					
83	inadequate access to agricultural extension services					
84	shortage of water for irrigation					
85	inadequate time for adaptation planning					
86	inadequate landholding					
87	inadequate labour force					

88. Please what other problems prevent you from adapting to drought?..

....

....

....

Thank you

B: PROTOCOL FOR FOCUS GROUP DISCUSSION

Dear participants,

The essence of this group discussion is to deliberate on farmers' vulnerability and adaptation to drought. Specifically, this exercise is aimed at examining how vulnerable farmers are to drought and the drought adaptation strategies they use. We shall also discuss the factors that constrain farmers' capacity to adapt to drought.

Feel free to participate in this exercise which is purely academic. You are therefore urged to participate and contribute positively towards the success of this study. You have the liberty to withdraw from the discussion any at point in time. Your identity will not be disclosed and you are highly assured of anonymity and confidentiality. You are also informed that both video and audio recordings of the group discussion will be taken.

Thanks for your participation and contribution.

1. How will you describe the extent to which crop farming in this area is being affected by drought?
2. What are the impacts of drought on livestock production in this community?
3. Describe how drought conditions have affected the physical environment of this community in terms of:
    i. Water availability
    ii. Water quality
    iii. Plant and vegetal life
    iv. Survival of wildlife
    v. Soil quality

vi. Outbreak of pests and diseases

vii. others

4. Does drought yield any positive impact? Yes [ ] No [ ]
5. If 'Yes', what are some of these positive impacts of drought?
6. How does drought affect the socio-economic activities of farmers in this community?
7. Generally, to what extent are farmers vulnerable to the impact of drought?

Ranking the following factors based on the perceived contribution of the various input factors to vulnerability by using the weighting scale 1-10

No.	**DROUGHT SENSITIVITY** **Social Indicators**	
A	Migration of people to other places	
B	Shortage of food	
C	Drop out of children from school	
D	Health impact (diseases and insect Infestation	
E	Disruption of festival celebration	

Economic indicators

F	Increased in food prices	
G	Reduction in crop yield	
H	Decrease of livestock	
I	Reduction in farm income	
J	Increased in livestock diseases	

L	Poor hunting activities	
M	Damage to property/assets	

Environmental indicators

N	Drying up of surface water (streams, rivers, ponds, dams etc)	
O	Decline in groundwater levels	
Q	Increase in average heat and temperature	
R	Reduction in soil moisture	
S	Destruction of vegetation	
T	Damage to wildlife	
U	Inadequate access to water	

8. As a farmer, what do you do when drought occurs?
9. What specific adaptation methods do they employ to cope with drought?
10. What adaptation methods are farmers unable to use to cope with drought?
11. As farmers, what factors hinder your capacity to adapt to drought?

C: INTERVIEW GUIDE FOR KEY INFORMANTS

The essence of this interview is to deliberate on farmers 'vulnerability and adaptation to drought. Specifically, this exercise is aimed at examining how vulnerable farmers are to drought and the drought adaptation strategies being used. We shall also discuss the factors that constrain farmers' capacity to adapt to drought.

Feel free to participate in this exercise which is purely academic. You are therefore urged to participate and contribute positively towards the success of this study. You have the liberty to withdraw from the interview session at any point in time. Your identity will not be disclosed and you are highly assured of anonymity and confidentiality. You are also informed that audio/video recordings of the interview will be taken.

1. Name of community……………………………………………..
2. Gender: Male [ ] Female [ ]
3. How old are you? ……………………………………..
4. How long have you been farming? …………………………...
5. Does drought affect your physical environment? Yes [ ] No [ ]
6. If 'Yes', how does it affect your physical environment?
7. Does drought affect plant growth in your community? Yes [ ] No [ ]
8. If 'Yes', how does it affect plant life?
9. How does drought affect your socio-economic activities?
10. Have you noticed some changes in your crop productivity as a result of drought? Yes [ ] No [ ]
11. If yes, what are some of these changes in crop production that you have noticed as a result of drought?

12. Does drought affect livestock production in this community?

    Yes [ ] No [ ]

13. If 'Yes', how does it affect your animal rearing activities?

14a. Do you practice drought adaptation? Yes [ ] No [ ]

14b. If 'Yes',

   i. What drought adaptation strategies do you adopt to cope with drought conditions before its occurrence?

   ii. As a farmer, what do you do when drought occurs?

   iii. After the occurrence of drought, what long-term measures do you adopt to cope with drought?

14c. What factors hinder your capacity to practice drought adaptation measures?

15. How do the afore-mentioned factors in Question 14c pose challenge to your capacity to adapt to drought?

14. Are there some drought adaptation measures that you are unable to practice? Yes [ ] No [ ]

15. If 'Yes', mention these measures that you are unable to practice.

16. Why are you unable to practice the above-mentioned drought adaptation measures?