Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given where reference has been made to the work of others.

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In writing these papers I received guidance from the co-authors. However, as the lead author I designed the research including the methodology and analysed the data. The contents draw directly from data I collected from my own fieldwork. I wrote the manuscripts and all authors contributed to the revisions and editing of these papers.

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Abstract

Sub-Saharan Africa is projected to be severely affected by climate change in the form of increased climate variability. Ghana provides a suitable case study country in which to assess the vulnerability of communities to such climate changes. Data on the nature and extent of vulnerability of Ghana's food production systems and livelihoods to climate variability (particularly drought) are lacking, and this hampers the development of effective policy to reduce the adverse impacts of climate change and variability. This study aims to enhance empirical understanding of the socioeconomic, institutional and biophysical factors that contribute to vulnerability to climate change and variability amongst a range of farming households and communities in Ghana. By integrating statistical analyses, participatory methods and ecological surveys, this research adopts a multi-scale approach to assess the extent of food production and livelihood vulnerability across multiple scales: mapping vulnerability at the national and regional scales and drilling down to the community and household scales. Results show that the vulnerability of crop production to climate variability (particularly drought) has discernible geographical and socioeconomic patterns, with the Northern, Upper West and Upper East regions being most vulnerable. The results of the drought assessment are used to guide local-level research, and demonstrate the need for region-specific policies to reduce vulnerability and enhance drought preparedness within dryland farming communities. Within the same agro-ecological setting, different communities and households experience different vulnerability attributed to differences in socioeconomic characteristics. Results show that vulnerability of farming households can be linked to access to livelihood capital assets and that vulnerable communities tend to have households that are characterised by low levels of human, natural, financial, physical and social capitals. Findings also demonstrate that small-scale farmers employ a range of on-farm and off-farm adaptation strategies including changing the timing of planting, planting of drought-tolerant and early maturing varieties of crops, livelihood diversification, agro-forestry systems, crop diversification, temporary migration, relying on social networks and reducing food consumption to manage climate variability. A range of challenges including a lack of financial resources, poor access to information on climate adaptation, complex land tenure systems, social-cultural barriers, limited access to improved varieties of crops, as well as a lack of institutional support, constitute serious barriers to adaptation.

Policy makers need to formulate specific and targeted climate adaptation policies that a) enable farmers to engage in alternative livelihood diversification strategies; b) promote the development and planting of improved varieties of crops; and c) allow for the provision of institutional support including access to information on climate adaptation and adequate all-year-round extension services. Such policies should be linked to programmes that foster asset building as well as enhance institutional capacity and social capital.

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List of Abbreviations

ANOVA	Analysis of Variance
CoP	Conference of Parties
DfID	Department for International Development, UK
EPA	Environmental Protection Agency, Ghana
FAO	Food and Agriculture Organisation
FASDEP	Food and Agriculture Sector Development Policy, Ghana
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GMet	Ghana Meteorological Agency
HLVI	Household Livelihood Vulnerability Index
IIED	International Institute for Environment and Development
INC	Initial National Communication, Ghana
IPCC	Intergovernmental Panel on Climate Change
ISSER	Institute for Statistical, Social and Economic Research, Ghana
MEST	Ministry of Environment, Science and Technology, Ghana
MLF	Ministry of Lands and Forestry, Ghana
MoFA	Ministry of Food and Agriculture, Ghana
MoFEP	Ministry of Finance and Economic Planning, Ghana
NAP	National Action Programme to combat desertification, Ghana
NCCAS	National Climate Change Adaptation Strategy, Ghana
NCCPF	National Climate Change Policy Framework, Ghana
NDPC	National Development Planning Commission, Ghana
NGO	Non-Governmental Organisation
NLP	National Land Policy, Ghana
SLA	Sustainable Livelihood Approach
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1

GENERAL INTRODUCTION

1.1 Research problem definition and justification

Climate change and variability pose one of the greatest threats to humankind in the 21st century (IPCC, 2007). Climate-crop modelling studies suggest that agriculture will be disproportionately affected compared with other sectors (Thornton *et al.*, 2011; Lobell *et al.*, 2008; Ericksen *et al.*, 2011). There is an urgent need for interdisciplinary work that combines insights into food production with socioeconomic evaluations of farming communities so as to better understand how climate change and variability may affect food production systems and rural livelihoods (Mueller *et al.*, 2012). An interdisciplinary approach allows different dimensions of climate change and variability to be explored. By bringing together different disciplines such as climate modelling, agricultural science, ecology and environmental sustainability, a more comprehensive explanation of climate change and its impacts on people can be achieved (Robinson, 2008; Kates *et al.*, 2001). This is particularly important in Africa, especially sub-Saharan Africa (henceforth, 'SSA'), which is projected to be severely affected by climate change and variability (Lobell *et al.*, 2011; Schlenker and Lobell, 2010; Boko *et al.*, 2007), and where a significant proportion of the people depend on rain-fed agriculture for their livelihoods (IPCC, 2007). An estimated 95% of farmed land in SSA is under rain-fed agriculture (FAO, 2005).

Africa has been reported as the most vulnerable region to climate change and variability as a result of its low adaptive capacity due to extreme poverty, poor infrastructure, insufficient safety nets and heavy dependence on rain-fed agriculture (Boko *et al.*, 2007). Climate models suggest that SSA will experience a temperature rise of 2–4^{o}C by 2100, which represents an increase of about 1.5 times higher than the projected mean global temperature increase (Christensen *et al.*, 2007; Boko *et al.*, 2007). In addition, increases in agricultural productivity have been slowest in SSA compared with the rest of the world (Dinar *et al.*, 2008). In an assessment of vulnerability to climate related mortality, 33 out of the 59 countries found to be highly or moderately-highly vulnerable were situated in SSA (Brooks *et al.*, 2005).

Ghana is an appropriate place to investigate these issues because agriculture is the backbone of its economy, contributing about 44% of the country's Gross Domestic Product (GDP). Agriculture is the main source of income for many low income Ghanaian families, employing about 57% of the population (ISSER, 2003), while the agricultural sector contributes significantly to the foreign exchange earnings of the country. It is also important to note that the agricultural sector contributes to development through its provision of raw materials to local industries (MoFA, 2007). In spite of its socioeconomic importance, Ghana's agricultural sector is arguably one of the most climate sensitive sectors because of its dependence on rain-fed cultivation. The amount and pattern of rainfall plays a key role in determining agricultural productivity (Haile, 2005). Maize yields in Ghana are projected to decrease by 7% by 2020 due to projected decreases in rainfall and increases in temperature linked to climate change and variability (EPA, 2008). This has the potential to severely affect food security because maize is grown and consumed in almost every part of the country.

Ghana has experienced considerable variations in temperature and rainfall patterns since the 1960s (EPA, 2003; 2007). Whilst uncertainties remain on future estimates of rainfall and temperature change, the general sense is that temperature will increase whilst rainfall decreases in all agro-ecological zones in Ghana (EPA, 2007). The ensemble of 21 climate models used by the Intergovernmental Panel on Climate Change (IPCC) suggest that there will be increased total precipitation in the south of the country whilst the northern parts of Ghana will become drier (Christensen *et al.*, 2007). For instance, the IPCC model ensemble has projected that a reduction of 80 mm in monthly rainfall is possible in the north, particularly during the June–August farming season (Christensen *et al.*, 2007). This will be exacerbated by high inter-annual rainfall variability, characterised by a reduction in the number of rainy days (Christensen *et al.*, 2007). Indeed, a 40 year series (1961–2000) of climate data from the Ghana Meteorological Agency (GMet) show a rise of about 1^{o}C in temperature and a decrease in rainfall and run-off by approximately 20% and 30%, respectively (EPA, 2007). Whilst the country's temperature has been predicted to increase, based on future climate change scenarios using General Circulation Models, by 0.6^{o}C, 2.0^{o}C and 3.9^{o}C by the years 2020, 2050 and 2080 respectively, rainfall, on the other hand, has been predicted to decrease by 2.8%, 10.9% and 18.6% during the same period (EPA, 2007).

For the past three decades, Ghana has experienced increased incidences of extreme events such as droughts, floods and bush fires linked to climate change and variability (Boko *et al.*, 2007; Christensen *et al.*, 2007) and these have often resulted in severe food insecurity (MoFA, 2007). Ghana experienced droughts in 1968–73, 1982–84, 1990–1992 but the drought of 1983/84 is one of the most major droughts in the country's history as it caused major hydrological imbalances that affected crop productivity throughout the country (EPA, 2003). For instance, Ofori-Sarpong (1986) observed a significant decline in cereal production due to the major drought in 1983 that led to extensive food insecurity. In terms of floods, 2007 recorded one of the most devastating floods to hit the country (especially northern Ghana) in recent years, with over 330,000 people affected and 56 killed (Tschakert *et al.*, 2010).

Increased temperature coupled with decreased rainfall will affect water resources. Though varying between regions, Owusu and Waylen (2009) observed downward trends in precipitation in most agro-ecological zones in Ghana between 1951 and 2000. Water flow in Ghana has been projected to decrease by 15–20% and 30–40% for the years 2020 and 2050 respectively (WRI, 2000; Owusu and Waylen, 2009). Reduction in water flow will result in enhanced soil moisture deficits and increased evaporation and evapo-transpiration, shortening the length of the growing season. This could have serious implications for agricultural productivity in several communities across the country. Coupled with extreme events such as droughts and floods, it could result in crop failure and food insecurity across many parts of the country.

Food security and rural livelihoods in Ghana and SSA more widely will therefore be placed under considerable stress due to climate change and variability (FAO, 2010). Cereals including maize, millet and sorghum, which serve as important staple food crops are extremely vulnerable (particularly to drought) (Schlenker and Lobell, 2010), as these crops require an appreciable quantity of rainfall for their growth. Using a crop model (CROPSIM-cassava) with data from the semi-deciduous forest zone (Ashanti region) of Ghana, Sagoe (2008) projected a reduction in predicted cassava yields of 3%, 13.5% and 53% by 2020, 2050 and 2080 respectively. Similarly, yields of cocoyam are expected to reduce by 11.8%, 29.6% and 68% in 2020, 2050 and 2050 respectively. In addition, the livelihoods of poor smallholder farmers are disrupted by drought and floods due to climate variability, thereby increasing their vulnerability to food insecurity (MoFA, 2007).

Land degradation including desertification and severe forms of soil erosion due to climate change compound the risk of food insecurity in most parts of the country (EPA, 2003). A model-based study of Ghana suggests that land degradation due to soil erosion could reduce agricultural income by US$4.2 billion over the period 2006–2015 (Diao and Sarpong, 2011). These challenges have the potential to make many households food insecure as they will have limited capacity in terms of food availability, access and utilisation.

The intra-annual rainfall variability and increased temperature are also situated in a myriad of other political, economic, social and environmental challenges (EPA, 2007). This has adverse consequences for Ghana's development because the economy is dependent on rain-fed agriculture. This shows that Ghana (particularly the agricultural sector), is extremely sensitive to the adverse impacts of climate variability (EPA, 2007; Stanturf *et al.*, 2011), hence the need to explore the extent of vulnerability and provide appropriate policy interventions.

Despite the projected decrease in rainfall and increase in temperature, data on the nature and extent of vulnerability of Ghana's food systems and rural livelihoods to climate change and variability are lacking and this hampers the development of effective policy to reduce the adverse impacts of climate change and variability. For instance, little is known about how farmers adapt to changing climatic conditions in different parts of the country. As such, it is unclear from a policy perspective how to best enhance national adaptive capacity. This research seeks to provide empirical understanding of the factors and drivers that contribute to vulnerability to climate change and variability in food production systems and rural livelihoods in Ghana and thereby provides insights into the processes that are needed to create the capacity to adapt. A better understanding of the risks posed by climate change and variability (particularly drought) will provide guided policy recommendations to improve food production, livelihoods and agricultural practices in Ghana.

Mapping climate vulnerability of Ghana is important because the IPCC's regional assessments of climate change impacts for Africa imply declining grain yields are likely and predict that agricultural production and food security in SSA will be negatively affected particularly relating to increased drought intensity and frequency linked to greater inter-annual rainfall variability (Boko *et al.*, 2007; Lobell *et al.*, 2008). However, the impacts of climate variability on food production in SSA will vary spatially and understanding the complexity of such systems requires further investigation through more detailed assessments of key regions such as that provided in this thesis.

The different agro-ecological zones of Ghana share climatic features similar to the Sahel and other parts of West Africa, which experience a high degree of temporal and spatial variations in rainfall and temperature (Hulme, 2001). For instance, the major drought experienced in Ghana in 1983/84 and flood of 2007 were also experienced in many other West African countries (FAO, 2009). In addition, the socioeconomic characteristics of Ghana in terms of poverty levels and per capita GDP (of less than US$1000 per year) are similar to those of other West African countries (UNDP, 2010). Like Ghana, rain-fed agriculture provides employment to more than half of all the population in most of West Africa (UNDP, 2010). Therefore, Ghana is a useful case study context in which to undertake more detailed climate vulnerability assessment, and the findings will have wider significance for dryland farming systems in Ghana and SSA more widely.

1.2 Research aim and objectives

The aim of this thesis is to explore the socioeconomic, institutional and biophysical factors that contribute to vulnerability to climate change and variability amongst a range of types of farming households and communities in Ghana. This will improve understanding of the links between Ghana's food production systems and climate change and variability. To achieve this aim, the specific objectives are to:

(1) Identify vulnerable and resilient regions, districts and communities in Ghana;

(2) Characterise and explain the nature of vulnerable and resilient households and communities based on farm, community, institutional and socioeconomic factors;

(3) Determine different adaptation strategies being adopted to manage climate change and variability in vulnerable and resilient households and communities;
(4) Identify and evaluate the main barriers to these adaptation strategies in vulnerable and resilient farming communities;
(5) Identify policy recommendations to reduce vulnerability and enhance resilience of food production systems and rural livelihoods to climate change and variability at local, regional and national scales.

1.3 Applied and academic contributions

By providing multi-scale, mixed methods research that addresses each of the objectives, this thesis provides several important academic contributions. It:

(i) Contributes to scientific debates on the development of integrated vulnerability assessments that can be applied in geographical areas for which more detailed data may be lacking. This is particularly important for Africa and Ghana in particular, where there are few climate projections due to lack of appropriate climate data.

(ii) Provides a theoretical understanding of food production and rural livelihood vulnerability that will help guide more general discussions of the sorts of livelihood systems that should be better able to adapt to future climate changes.

(iii) Increases understanding of the drivers of vulnerability to climate change and variability in agriculture-dependent households in order to enhance the design and implementation of specific climate adaptation policy.

(iv) Contributes to scientific debates by increasing our understanding of how small-scale farmers are coping with the challenges posed by climate variability.

(v) Provides insights into the barriers to small-scale farmers' climate adaptation pathways in the context of rain-fed agriculture, thereby providing guided policy recommendations to help enhance food production and reduce livelihood vulnerability in Ghana and more widely.

1.4 Definition of key terms and concepts

In the climate change literature, there are no universally agreed definitions for terms such as vulnerability, adaptation, and resilience. Given that definitions of these terms and concepts are often contested, working definitions are provided here and applied throughout this thesis. Justifications for the chosen definitions are provided to frame the analysis and discussions.

Vulnerability: This thesis adopts the IPCC definition of vulnerability (to climate change) as "the degree to which an environmental or social system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes" (IPCC, 2007, p. 883). The IPCC indicates that vulnerability is a function of a system's exposure, sensitivity and adaptive capacity (full explanation of these terms – exposure, sensitivity and adaptive capacity – is provided later, in Chapter 2).

Adaptation: This thesis follows Smith *et al*'s (2000) definition of adaptation as the process by which stakeholders reduce the adverse effects of climate on their livelihoods. It involves adjustments in lifestyle, behaviour and economic structure aimed at reducing the vulnerability of a system to climate change, thereby increasing its sustainability (Smith *et al.*, 2000).

Resilience: According to Walker *et al*. (2006), resilience refers to the ability of a system to withstand shocks in order to maintain its structure and identity. Resilience is defined as being present in situations where major changes and variability in the climate (such as drought) result in insignificant loss of crop yield in a particular community (Simelton *et al.*, 2009).

Adaptive capacity: Adaptive capacity in the context of climate change has been defined by the IPCC (2007, p. 869) as "the ability of a [food production] system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." This research adopts the definition by the IPCC because it allows a broad conceptualisation of what farming communities are doing and the resources they draw upon in adapting to climate variability.

Coping capacity: Coping capacity and adaptive capacity are mostly distinguished with reference to timescale. Adaptive capacity is linked to long-term strategies whilst coping may include short-term strategies (Smithers and Smit, 1997). In this thesis, coping capacity refers to short-term strategies taken by farming households and communities to counteract the immediate negative impacts of climate variability including drought (Campbell *et al.*, 2011).

Food systems: According to Ericksen (2008a, p. 3), "food systems comprise a set of activities and outcomes ranging from production through to consumption, which involve both human and environmental dimensions." Gregory *et al.* (2005, p. 2141) defined food system as "a set of dynamic interactions between and within the bio-geophysical and human environments which result in the production, processing, distribution and preparation and consumption of food." This research will follow the definition by Gregory *et al.* (2005) as a working definition but focuses specifically on food production systems.

Food security: Several definitions have been proposed for food security over the years. Having recognised the diversity in definitions of food security, this thesis adopts the FAO (2002) definition as a "situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."

Drought: this thesis adopts the IPCC (2007, p. 873) definition of drought as a "phenomenon that exists when precipitation is significantly below normal recorded levels causing serious hydrological imbalances that adversely affect land resource production systems." This thesis is concerned with meteorological drought, which refers to lack of precipitation over a particular period, and agricultural drought, which refers to "periods of declining soil moisture and consequent crop failure" (Mishra and Singh, 2010, p. 206).

Livelihoods: "A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway, 1992, p. 7). An assessment of livelihoods offers the opportunity to highlight the various adaptations that might be available to determine how rural communities can cope with declining crop yields due to drought.

1.5 Structure of thesis

This thesis is structured into nine chapters that are linked to the research objectives. Following this introductory chapter, Chapter 2 reviews the pertinent literature on climate change and variability and the impacts of these on food production systems and livelihoods with particular reference to SSA. In addition, Chapter 2 highlights literature on various frameworks that have been used to assess the vulnerability of food production systems and livelihoods to climate variability, and explores the literature on climate adaptation in SSA.

Chapter 3 describes the study country (Ghana) highlighting the nature of its farming and land tenure system. The research design and methodology are also presented in Chapter 3, describing the study locations and the range of quantitative and participatory methods used to collect and analyse data. The relevance of participatory approaches for this thesis is discussed in Chapter 3. Also, Chapter 3 explores the strengths and limitations of the research instruments used for data collection. Finally, issues relating to positionality and ethical considerations are explored in Chapter 3.

Chapter 4 develops and applies a multi-scale, multi-indicator method to assess food production vulnerability to drought in Ghana. This integrated method is used to identify resilient and vulnerable regions and districts, within which expert and stakeholders' interviews were used to select specific resilient and vulnerable farming communities for local-level research. Chapter 4 also assesses the extent of climate change and variability in the study area.

In Chapter 5, food production systems in the identified resilient and vulnerable communities are characterised. Applying the sustainable livelihoods approach, this chapter builds on Chapter 4 (national and regional level assessments) by developing and applying a household livelihood vulnerability index at the community and household scales to characterise and explore the nature of climate vulnerability. Chapter 5 identifies outlier households (i.e. vulnerable households within resilient communities as well as more resilient households within vulnerable communities). Outlier households are studied in detail to explain the factors that can help households to be more resilient or vulnerable.

In Chapter 6, the main adaptation strategies used by households in the farming communities are identified and evaluated. This chapter also assesses the socioeconomic factors that may influence households' choice of specific adaptation strategies. Chapter 7 then determines the major barriers preventing households in the farming communities from implementing such adaptation strategies.

Chapter 8 analyses the various policies aiming to tackle climate change and desertification. It also analyses policies on food security in Ghana. In Chapter 8, the possible policy interventions identified in this thesis that can be used to reduce the adverse impacts of climate change and variability on food production systems and rural livelihoods are also presented.

Chapter 9 summarises the main conclusions and provides a synthesis of the key findings, exploring the implications for food security and rural livelihoods in Ghana and more widely. Chapter 9 also provides methodological reflections on the multi-scale drought vulnerability assessment. Finally, priorities for future research are presented in Chapter 9.

1.6 Conclusion

This chapter has stated the research problem and outlined the main research objectives that this thesis seeks to achieve. It has also highlighted the envisaged academic contribution of the research and established the need for research of this nature to be conducted to improve understanding of the links between Ghana's food production systems and climate change and variability.

CHAPTER 2

ASSESSING VULNERABILITY IN FOOD PRODUCTION SYSTEMS TO CLIMATE VARIABILITY

2.1 Introduction

This chapter reviews pertinent literature on vulnerability assessment to establish the theoretical and conceptual frameworks for the thesis. It identifies gaps in the literature that inform the appropriate research design and methods outlined in Chapter 3. This chapter begins by examining literature on the extent of climate change and variability with particular reference to SSA. It then examines the implications of climate variability for food security in SSA by highlighting the impacts of climate change and variability on different components of food security: food availability, accessibility, utilisation and stability. The chapter provides a review of the relevant frameworks that have been proposed to assess vulnerability to climate change and variability. It then highlights pertinent literature on climate adaptation measures with reference to SSA. The chapter concludes with a synthesis and reflection, highlighting the main research gaps that the thesis addresses.

2.2 Climate change and variability in Sub-Saharan Africa

Although Africa is considered a minor player in terms of total global greenhouse gas emissions, contributing to <3% of the world's total (UNDP, 2007), international studies (e.g. Boko *et al.*, 2007; Lobell *et al.*, 2011) suggest that Africa is the most vulnerable continent to climate change and variability. This vulnerability has been attributed to the continent's low adaptive capacity and its over-dependence on rain-fed agriculture (Boko *et al.*, 2007). Rain-fed agriculture provides the backbone of most African countries' economies, employing about 60% of the workforce (Sarris and Morrison, 2010). Within Africa, SSA is considered to be the most vulnerable to the adverse impacts of climate change and variability (Boko *et al.*, 2007).

Hulme *et al*. (2001) indicated that Africa is warmer than it was 100 years ago, with greater warming occurring since the 1960s. Many studies have established that there have been remarkable changes in rainfall, temperature as well as increased incidence of extreme weather events across Africa, particularly SSA (Hulme *et al.*, 2001; Nicholson, 2001; Nicholson *et al.*, 2000). Decadal warming rates of 0.29^{o}C have been observed for Africa in general (Boko *et al.*, 2007). In terms of future trends, Christensen *et al*. (2007) project an average increase of between 3^{o}C and 4^{o}C for Africa by 2080–2099 based on the 1980–1999 period, under medium-high IPCC emission scenarios, using the 20 General Circulation Models. SSA has experienced both seasonal and annual rainfall variability (Hulme *et al.*, 2001). Several studies investigating rainfall variability have noted a decline in annual precipitation in SSA, especially West Africa, and particularly in the Sahel (Hulme *et al.*, 2001; Nicholson, 2001). The El Niño phenomenon, sea–surface temperatures and, the feedback between land and the atmosphere have been identified as important influences on rainfall variability (Nicholson, 2000). Ghana, like many other West African countries has experienced considerable variations in temperature and rainfall patterns over the past four decades (EPA, 2007). Several studies have projected that temperature will increase and rainfall will decrease in all of the country's agro-ecological zones (e.g. EPA, 2007; Owusu and Waylen, 2009). Hence, Ghana provides a useful case study country in which to explore the links between vulnerability to climate change, food production and livelihoods.

2.3 Implications of climate change and variability for food security in Sub-Saharan Africa

Food systems are defined in this research as "a set of dynamic interactions between and within the bio-geophysical and human environments that result in the production, processing, distribution, preparation and consumption of food" (Gregory *et al.*, 2005, p. 2141). From this, it can be deduced that food systems are central to achieving food security within a region. Though food security remains an elusive concept (Barrett, 2010), generally, it consists of four key components: (i) food availability (production, distribution and exchange); (ii) food accessibility (affordability, allocation and preference); (iii) food utilisation (nutritional value, social value and food safety); and (iv) food stability (Schmidhuber and Tubiello, 2007; Ingram *et al.*, 2005). Failure in one of these components can result in a household becoming food insecure (Ericksen, 2008a). Much of the literature suggests that food security could be threatened by climate change together with other factors such as increasing population, consumption patterns and urbanisation (Godfray *et al.*, 2010; Satterthwaite *et al.*, 2010; Beddington, 2010).

Food security is influenced by the interplay of a complex set of economic and socio-political factors including poverty, lack of markets, accelerated population growth, poor infrastructure, conflicts, and a high disease burden – aspects that characterise most economies in SSA (Ericksen, 2008b). Climate change and variability will add to these factors. Climate change has been described as a new security threat to Africa (Brown *et al.*, 2007), with a recent study suggesting increased incidences of civil wars due to climate change and a strong correlation between historical civil wars and warmer years (Burke *et al.*, 2009). Climate change and variability will adversely affect all four components of food security, highlighting the need for policy makers to implement appropriate measures to mitigate these impacts (Kotir, 2011). The next section examines how the components of food security could be adversely impacted by climate change and variability. Since this thesis is primarily concerned with food production aspects of food system, emphasis is placed on food availability as this is the aspect to which food production is most closely linked.

2.3.1 Food availability

Food availability can be defined as the quantity of food produced within a particular region including the distribution and exchange of these foods (FAO, 2008). Ericksen (2008b) argues that human capital and landholding size among other factors may influence the amount of food produced within a particular region. Several studies have suggested that food production in Africa, especially SSA, will be adversely affected by climate change and variability (Schlenker and Lobell, 2010; Boko *et al.*, 2007; Thornton *et al.*, 2011; Kotir, 2011). Boko *et al*. (2007) project about 50% reductions in crop yield by 2020 with an estimated 90% fall in crop net revenue by 2100 due to climate change in many Africa countries. Schlenker and Lobell (2010) modelled yield response to climate change by combining climate data with historical crop production to show that yields of major agricultural crops including maize, groundnut, millet, sorghum and cassava in SSA, could decrease by 7–27 % by mid-century (2050).

Climate change and variability will affect food availability in SSA by reducing the area of crop land suitable for agricultural production (Arnell, 2009). Much of SSA will experience a substantial reduction in the length of growing period, i.e. when soil moisture and temperature are most conducive for crop growth (Thornton *et al.*, 2011). Warming by 4^{o}C or more could have devastating effects on the livelihoods of many croppers and livestock keepers in SSA (Thornton *et al.*, 2011), especially where rain-fed agriculture contributes about 30% of GDP (Sarris and Morrison, 2010).

Changes in environmental conditions that control plant growth such as temperature, soil moisture and atmospheric carbon dioxide could alter crop production. Climate change and variability can also affect the incidence of pests and diseases that could reduce agricultural productivity (Gan, 2004). Crop yields may be directly affected by climate change especially in rain-fed agricultural systems. For instance, high temperatures during flowering could be very costly for crops such as maize and soybean (Porter and Semenov, 2005). This is because physiological processes such as germination, flowering and photosynthesis have an optimum temperature range within which they function effectively (Gliessman, 2007).

Extreme weather events due to climate change may make the application of farm inputs such as fertilizers difficult and this can reduce their efficiency (Porter and Semenov, 2005). Climate change may also increase the risk of soil erosion and salinization (Nearing *et al.*, 2004). This is likely to reduce soil fertility, especially in arid and semi-arid regions, where there are serious challenges posed by land degradation and desertification. This may reduce crop yields. Further, drought as a result of increased temperature and reduced precipitation could pose serious challenges to many poor small-scale farmers. The few irrigation facilities in SSA could be placed under considerable pressure (IPCC, 2007). It is estimated that climate change will expose between 75–250 million people to water stress in Africa by the 2020s (Arnell, 2004). Worryingly, this figure could increase to 350–600 million people by the 2050s (Arnell, 2004). This will lead to increased competition for water between agricultural, household and industrial purposes that could lead to conflicts (see Toulmin, 2009).

The impacts of climate change on human health may also indirectly affect agriculture. In SSA where temperatures are already high, any further increases can be very dangerous for human health, increasing the incidence of diseases such as diarrhoea, and malaria (Confalonieri *et al.*, 2007; Haines *et al.*, 2006). For instance, Campbell-Lendrum *et al.* (2003) project increases of 2–3% of diarrhoea cases by 2020 due to climate change in low income countries. Increased incidence of malaria due to climate change could also potentially affect labour availability for agriculture (Confalonieri *et al.*, 2007), with considerable implications for food availability (Tirado *et al.*, 2010). Under the HadCM2 climate scenario, Parry *et al.* (1999) estimate an additional 55–65 million people are likely to suffer from hunger by the 2080s.

The distribution of food is essential if food is to be made available, especially in developing countries that lack the infrastructural capacity to store and transport food from production centres to other areas. Food needs to be moved from areas of production to consumption through various transport systems. In this regard, increased incidences of extreme events such as flooding, rain storms and heat stress due to climate change across Africa (IPCC, 2007) could have devastating effect on food availability by disrupting road infrastructure, making food distribution quite challenging.

2.3.2 Food accessibility

Food accessibility is defined as the ability of the individual or household to secure entitlements which will allow the individual or household to acquire food in sufficient quantities and quality (Schmidhuber and Tubiello, 2007). Food accessibility is influenced by three major factors; affordability, allocation and preference (Ericksen, 2008b; Ingram *et al.*, 2005). Food affordability refers to a household's ability to access food through its set of entitlement and usually varies across different income classes within a particular region or community (FAO, 2008). Climate change and variability will greatly affect households' or people's entitlements due to increased exposure resulting from climate change.

Climate change and variability may also increase the production cost of food, thereby increasing prices for consumers (FAO, 2008). This will affect food access by households in SSA (FAO, 2011). It is estimated that by 2080 climate change could reduce agricultural GDP in SSA by 8% compared with a decline of about 4% in Asia (Shah *et al.*, 2008). This will greatly affect the capacity of people to access food as a reduction in GDP will seriously compromise the ability to finance food exports for most countries in this region (Shah *et al.*, 2008). Reduced income to farmers in SSA due to reduced crop yields may affect the ability of most households in SSA to purchase food, even when food is available on the market. It is projected that an increase of $3^{o}C$ and beyond could result in up to a 40% increase in food prices (Easterling *et al.*, 2007).

2.3.3 Food utilization

Food utilization refers to the use of a particular food which is determined by its nutritional value, social value and safety (Ericksen, 2008b; FAO, 2008). Food utilization also concerns the dietary quality of food (Barrett, 2010). Increasing temperatures associated with climate change could affect the quality of food in storage, thereby affecting local food supplies, particularly in SSA (Tirado *et al.*, 2010). This will be especially significant for vegetable crops, which have a short shelf life. Developed nations may be able to invest heavily in storage facilities that will reduce these impacts on food quality (FAO, 2008). However, this is likely to present serious challenges for developing countries (including those in SSA), which already have lots of developmental issues with which to contend. It has also been observed that climate change and variability could directly adversely affect the nutrient contents of food such as grains, as well as increase toxins in food as a result of increased incidences of pests and diseases (Slingo *et al.*, 2005). Mycotoxin (including aflatoxin) contamination of groundnut has been cited as one possible concern (Slingo *et al.*, 2005). Food utilisation may also be related to the impacts of climate change on the ability of individuals to utilise food due to increased incidence of diseases.

2.3.4 Food stability

Food stability refers to situations where people may either temporarily or permanently lose their access to resources that could enable them consume food (Schmidhuber and Tubiello, 2007). The impacts of climate change and variability on food stability relates to the increased incidence of extreme events such as cyclones, droughts and floods that will ultimately affect the stability of local production and supplies (IPCC, 2007). Food instability due to drought has also been reported to result in a dramatic reduction in agricultural production (including livestock) with SSA and parts of South Asia – two of the poorest regions in the world – predicted to experience the highest degree of chronic undernourishment (Bruinsma, 2003).

The on-going discussions show that all components of food security will be negatively affected by climate change and variability. In SSA, this challenge is further complicated by a lack of institutional and scientific capacity to address the problems presented by increased temperature and reduced rainfall on the livelihoods of rural households and communities. Food security in many SSA countries will, therefore, be placed under considerable stress due to climate change and variability.

Thus far, this review has established the extent of food systems' vulnerability to climate change and variability with particular reference to SSA. What follows is an exploration of the concept of vulnerability and how food systems and livelihood vulnerability to climate variability have been assessed.

2.4 Vulnerability to climate change and variability

The concept of vulnerability emerged within development debates in the 1990s (Chambers, 1994) and has also been applied in the area of hazard preparedness, engineering based research and projects (Adger, 2006). It has been applied to a wide range of challenges including food insecurity (e.g. Sen, 1981; Yaro, 2004), disaster assessment (e.g. Wisner, 2004; Cutter *et al.*, 2003) and in assessing livelihoods and poverty (e.g. Chambers and Conway, 1992) as well as climate vulnerability (e.g. Midgeley *et al.*, 2011; Abson *et al.*, 2012; Ericksen *et al.*, 2011). To understand how vulnerability is used in the climate change literature, this thesis first defines vulnerability and then explores the various interpretations by different scholars.

2.4.1 Vulnerability defined

There is a variety of definitions for vulnerability in the climate change literature and there is no consensus among scholars on what vulnerability is (Table 2.1). This thesis adopts the IPCC definition of vulnerability (to climate change) as "the degree to which an environmental or social system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007, p. 883). This allows broad conceptualisation of the extent to which farming communities and households are unable to withstand the negative impacts of climate variability on livelihoods, allowing the identification of the various adaptive capacities of such communities and households. Scholars working on livelihoods and vulnerability, such as Chambers (1989) and Watts and Bohle (1993), distinguish between the external and internal side of vulnerability. The external side relates to the stress that a system or individual is exposed to; and the internal side refers to a lack of inherent ability to cope and recover from a stress or hazard (Birkmann, 2006; Füssel and Klein, 2006).

A discussion of vulnerability should include the capacity of the system to withstand the threat posed by the changing environmental (climate) patterns (Moser, 1998). Therefore, Moser (1998) links vulnerability to asset ownership, as well as the entitlement that the household or community can command in the face of exposure. Hence, communities or households that have fewer assets are more vulnerable compared with those that can command more assets in the face of drought-related crisis such as famine (Moser, 1998). Thus, a system that is vulnerable to climate variability will demonstrate a high sensitivity to modest climate stress and is constrained in its capacity to adapt to such harmful effects (Lioubimtseva and Henebry, 2009).

Central to the interpretation and understanding of vulnerability is the idea of resilience of social-ecological systems (Miller *et al.*, 2010). Though resilience and vulnerability are closely related, care should be taken not to confuse resilience as a flip side of vulnerability (Gallopín, 2006). According to Walker *et al.* (2006), resilience refers to the ability of a system to withstand shocks in order to maintain its structure and identity. In his seminal paper, Holling (1973, p. 14) defines ecological resilience as the "ability to absorb change and disturbance and still maintain the same relationships that controls a system's behaviour." Social resilience refers to the capacity of social group or community to withstand socio-political as well as environmental stresses (Adger, 2000). Fraser (2006) argues that where a seemingly large disturbance causes relatively small shift in a system's original state, then such a system may be resilient. Resilience is defined in this research as situations where major changes and variability in the climate (such as drought) resulted in insignificant loss of crop yield in a particular farming community (Simelton *et al.*, 2009).

Table 2.1: Some definitions of vulnerability in the climate change literature

Author(s)	**Definitions**
Luers (2005)	Vulnerability is simply the susceptibility to harm by climate stress.
Watts and Bohle (1993)	Vulnerability to food insecurity can be conceptualised to consist of exposure, capacity and potentiality.
Cutter (1996)	Vulnerability is defined as the potential for loss.
Moss *et al.* (2001)	Vulnerability is the extent to which a particular system or society experiences disruption due to changes in the climate.
Turner *et al.* (2003, p. 8074)	Vulnerability is "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor."
IPCC (2007, p. 883)	Vulnerability is "the degree to which an environmental or social system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes."
Adger (2006, p. 268)	Vulnerability is the "state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt."
Fraser (2007); Simelton *et al.* (2009)	Vulnerability of an agricultural system refers to a situation where slight changes in the climate have significant impacts on agricultural yields due to lack of adaptive strategies to buffer yields against the adverse impact of the weather.

Factors such as access to capital assets, social networks and the availability of formal and informal institutions are vital in shaping the resilience of a particular community (Walker *et al.*, 2006; Osbahr *et al.*, 2010). Consideration of resilience in this thesis provides the opportunity to explore livelihood dynamics in order to understand the capacity of a particular community to withstand climate variability (Marschke and Berkes, 2006).

Several writers (e.g. Cutter *et al.,* 2003; Eakin and Luers, 2006; Gunderson and Holling, 2002) have suggested that vulnerability is as a result of various changes in the coupled socio-ecological system. In this case, social and ecological sub-systems are coupled, suggesting that socio and ecological vulnerabilities may be related (Turner *et* *al.*, 2003). Social vulnerability is “the exposure of groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods” (Adger, 1999, p. 249). Indeed, social vulnerability focuses on those characteristics of the population such as gender, age, ethnicity and other socioeconomic factors that could influence the ability of a particular community or household to withstand unexpected shocks to their livelihoods (Cutter *et al.*, 2009). In this case, consideration of social vulnerability enhances understanding of why certain communities (or individuals within the same community) are more vulnerable than others (Cutter *et al.*, 2009) (see Section 2.5.2.1 for the links between vulnerability and access to livelihood assets).

2.4.2 Competing interpretations of vulnerability assessments

Two competing interpretations of vulnerability to climate change include an ‘end-point’ approach and a ‘starting-point’ approach (Füssel and Klein, 2006; Kelly and Adger, 2000). In the end-point approach the “assessment of vulnerability is the end-point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options” (Kelly and Adger, 2000, p. 327). In this case, vulnerability is defined as the residual consequence of such assessment after feasible adaptation has been taken into considerations (Fussel, 2007). In the starting-point approach, vulnerability of a system or individual refers to the current state or the pre-existing incapacity to withstand shocks imposed by climate variability and change (O'Brien *et al.*, 2007). Starting point analyses consider vulnerability as an interplay of multiple factors within the socio-ecological systems (Kelly and Adger, 2000; O'Brien *et al.*, 2007). Starting-point analyses seek to examine the fundamental drivers of vulnerability and therefore provide a wider scope of policy intervention compared to the end-point vulnerability analyses (Eriksen and Kelly, 2007). One characteristic difference between the two approaches is the way they view adaptations. Whilst the end-point analyses maintain that adaptive capacity of particular system determines its vulnerability, the starting-point approach considers that it is rather vulnerability that determines the adaptive capacity and adaptation of a particular system (Füssel and Klein, 2006).

This thesis adopts the starting-point approach by assessing the current vulnerability of food production systems and livelihoods to climate variability in households and communities, thereby identifying inherent adaptive capacity that might be used to cope and adapt to climate variability. This can inform policies aimed at reducing the vulnerability of such communities and households. Indeed, dryland farming communities, have coped with climatic variability as part of their farming systems for centuries (Vogel, 2005). It is, therefore, vital that these coping and adaptive capacities are explored in an attempt to determine the extent of vulnerability of such communities to climate variability.

2.4.3 Vulnerability is context-specific and dynamic

Vulnerability is context-specific and what makes one region or community vulnerable may be different from another (Brooks *et al.*, 2005; Füssel, 2010). For instance, Simelton *et al.* (2012) revealed insightful factors that are significant in determining adaptive capacity by highlighting that socioeconomic factors that drive cereal production's vulnerability to drought depend on the type of cereal as well as the region of the world. They observed that regions characterised by high levels of GDP in agriculture as well as cereal intensity and fertilizer use demonstrated lower vulnerability, and that countries with "full democracies" were less vulnerable than those with "authoritarian" and "flawed democracies". This study concluded that poor and rich nations tend to be less vulnerable than middle income nations.

There are certain generic determinants of vulnerability including developmental factors that are likely to influence the vulnerability of a particular region or community even in diverse socioeconomic context (Brooks *et al.*, 2005). Thus, one of the key features of vulnerability is its dynamic nature that may change as a result of alterations in the biophysical as well as the socioeconomic characteristics of a particular region or community (Cutter *et al.*, 2009; Smit and Wandel, 2006). The dynamic nature of vulnerability means that assessments should be on-going processes in order to highlight the spatial and temporal scales of vulnerability of a particular region or community (Luers, 2005; Eriksen and Kelly, 2007).

In the IPCC Fourth Assessment Report, the vulnerability of a system to climate change is characterised as a function of the exposure, sensitivity and adaptive capacity of the system (IPCC, 2007). Nevertheless, the relationship amongst these components of vulnerability is ambiguous and not clearly defined (Eakin and Luers, 2006; Hinkel, 2011). These components are expanded upon in the following sections to enable a more in-depth understanding of the conceptual basis of these components.

2.4.4 Components of vulnerability

Adaptive capacity in the context of climate change has been defined as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007, p. 869). Engle (2011) is of the view that adaptive capacity generally connotes some positive attributes of a system that enable it to reduce the adverse impacts (vulnerability) associated with climate change. In this case, coping capacity has been used interchangeably with adaptive capacity in the climate change literature. These two terms are mostly distinguished with reference to timescale (Smithers and Smit, 1997) with adaptive capacity being linked to long-term strategies whilst coping capacity may refer to short term strategies. Coping capacity may be applied when attempts are made to manage current stresses/stressors and may be reactive in nature whilst adaptive capacity refers to preparing in anticipation of future uncertain changes thereby reducing vulnerability (Ericksen, 2008a). Coping responses are taken within the existing institutional structures of the system under consideration whilst adaptive capacity demands some transformation in terms of structure and functioning of the existing institutional structures (Eriksen *et al.*, 2005). Moreover, to be able to properly characterise the vulnerability of a given system, it is vital that the adaptive capacity of that particular system be identified or explored because every system has some inherent adaptive capacity to environmental change (Gbetibouo *et al.*, 2010).

Adaptive capacity can change over time and depends on several factors including technology, access to economic resources, access to information, infrastructural development, appropriate institutions, kinship network, literacy levels, skills, equity and political influence (Smith *et al.*, 2000; Brooks *et al.*, 2005). These determinants of adaptive capacity are "not independent and may function differently in different contexts" (Smit and Wandel, 2006, p. 288). Adaptive capacity may differ from one country, region or community to another and it is considered dynamic in nature (Smit and Wandel, 2006). Nonetheless, in terms of scales, it may be inter-dependent. For instance, the ability to withstand environmental stresses at the household level is greatly influenced by the socioeconomic processes occurring at the community and regional levels (Yaro, 2006). Hence, there is the need to bridge these different levels to provide a comprehensive understanding of how different processes interact at different scales to influence adaptive capacity, and ultimately vulnerability. This thesis addresses this gap by adopting a multi-scale approach to drought vulnerability assessment and exploring the various adaptive strategies that households and communities may use to withstand the negative impacts of drought.

Exposure relates to the extent to which a particular system or community may be exposed to climatic stresses (O'Brien *et al.*, 2004a). As such, a community or system must be first exposed to a stress to be vulnerable (Ericksen, 2008a). Synergies amongst different socioeconomic and political drivers could add to environmental stress, creating double or even multiple exposure scenarios (O'Brien *et al.*, 2004a). On the other hand, sensitivity determines the response of a given system to climate change and may be influenced by socioeconomic and ecological conditions of the system (IPCC, 2007). Hence, sensitivity is determined by the function of the inherent characteristics of the system being exposed, as well as the extent of stress on that particular system (Smit and Wandel, 2006).

Reidsma *et al*. (2007) differentiate between potential and actual impacts of climate change on a particular system or community in relation to climate exposure and sensitivity. The potential impact of climate change is a function of the exposure and sensitivity of the given community without taking into consideration its adaptive capacity, whilst the actual impact is that when adaptation has been considered (Reidsma *et al.*, 2007). At the household level, Smit and Wandel (2006) argued that the concepts–exposure and sensitivity–as determinants of vulnerability may be inseparable. Hence, the extent of adaptive capacity may be responsible for varying degrees of vulnerability amongst individuals or households within the same community (Eakin and Bojorquez-Tapia, 2008). This is also reflected in the livelihood characteristics of the individuals within such communities, which directly or indirectly affect the extent of exposure and sensitivity to a particular climate anomaly (Smit and Wandel, 2006). The availability of, and accessibility to, assets and resources to individuals and society may influence the extent to which they are vulnerable to the impacts of climate change. Thus, systems (or communities) that have more adaptive capacity are less vulnerable than those that are characterised by lower levels of adaptive capacity (Smit and Wandel, 2006). Also, the entitlements of individuals to capital assets including social, financial, human, physical and natural capitals could affect the individual's ability to cope with the impacts of climate change (Sen, 1981; 1999). What follows is a review of the key conceptual frameworks that have been used to assess vulnerability to climate change and variability.

2.5 Conceptual frameworks for assessing vulnerability to climate change

The purpose of vulnerability research is to provide a holistic comprehension of the causes of vulnerability so as to enhance the identification of various opportunities that could be used to cope with and adapt to such underlying causes (Miller *et al.*, 2010). Such an understanding will help to develop appropriate policies and strategies to reduce the risks posed by climate change and variability (Füssel and Klein, 2006). Assessing vulnerability has always been difficult because of its dynamic nature relating to its spatial and temporal dimensions (Cutter *et al.*, 2009; Eriksen and Kelly, 2007). Nevertheless, several scholars (e.g. Turner *et al.*, 2003; Luers *et al.*, 2003; Fraser *et al.*, 2005) have proposed different theoretical frameworks for the assessment of vulnerability to climate change and variability.

2.5.1 Entitlement-based approach

The entitlement based approach uses the development economics literature to explain how food insecurity occurs. The entitlement approach was developed in the early 1980s based on the pioneering work of Sen (1981) on '*Poverty and Famine'*. This marked the beginning of a paradigm shift to the study of food insecurity (which was hitherto based on Malthus's work[1]) by shifting the emphasis from mere availability to accessibility of food by individuals or households (Devereux, 2001). Hence, the entitlement theory displaced the prior notion that a shortfall in agricultural production was the main cause of food insecurity, arguing that people's access to food depends on their entitlement bundles. It therefore uses economic and institutional factors to explain vulnerability to food insecurity (Sen, 1981).

Entitlements are "the set of alternative commodity bundles that a person can command in society using the totality of rights and opportunities that he or she faces" (Sen, 1984, p. 497). Entitlements include the resources (either actual or potential) including reciprocal arrangements, production and productive assets that may be available to a household or community in the face of hardships (Sen, 1984). This means that the mere fact that food is available on the market does not necessarily guarantee its accessibility by an individual or a household. Thus, a household's level of entitlements determines the extent of its vulnerability to a particular food crisis (Sen, 1981). Food insecurity may occur when households or individuals are not able to access food through their entitlements even when there is adequate food supplies (Devereux, 2001).

Sen identifies four types of relation regarding entitlements; production, trade, labour and inheritance or transfer, and argues that an individual can access food directly or indirectly through these four means. Three major types of food entitlements may be identified: (i) direct entitlements in which the household produces its own food; (ii) indirect entitlement whereby the members of the household buys food from the market; and/or (iii) situations where households obtain food from charity or non-governmental organisation (NGOs) or through transfer of money from family and friends, which constitute transfer entitlements (Fraser *et al.*, 2005). Households may also become vulnerable to food insecurity when they cannot access food because of disruption in their entitlement bundles and they lack capacity to switch their food entitlement strategies (Fraser *et al.*, 2005).

[1] Early theories on famine and food insecurity were heavily influenced by the work of Malthus. Malthus '*Essays on the Principle of Population*' theorised that demand for food increases as population increases and that famine was nature's way of checking population growth (Devereux, 2001). This theory sought to explain famine as a natural phenomenon which might be exacerbated by excessive population growth.

2.5.1.1 Criticisms of the entitlement approach of vulnerability assessment

Several authors have criticised the entitlement approach for over-emphasising economic market-based causation. By focusing exclusively on economic factors, this approach fails to appreciate bio-physical and socio-political factors that could greatly influence food insecurity in a particular region as well as the way in which people construct their livelihoods to withstand the impacts of such situations (de Waal, 1990). For instance, the outbreak of diseases and widespread epidemics may account for the majority of people who die during period of food insecurity instead of a lack of appropriate food (de Waal, 1990).

Further, the entitlement approach may be too narrow by focusing only on food as the final outcome (Yaro, 2004). Indeed, achieving food security may not necessarily imply livelihood security since food security is just a part of livelihood security (Davies, 1996). In this case, since the entitlement theory is about individual food security, applying this concept to the larger population may be difficult (Yaro, 2004). Moreover, by focusing only on an individual's endowment and entitlement sets[2] to analyse their food security, it is possible to miss several critical variables that could potentially influence food security at the macro-societal level (Yaro, 2004). Indeed, decisions at the household level regarding production and purchases may be greatly influenced by major economic and social factors prevailing at the community and regional levels and these should be considered in a holistic understanding of food insecurity assessment.

By focusing on market-based economic failures, the entitlement approach fails to account for the role of government policies in food insecurity. Political theory argues that food insecurity may occur as a result of bad agricultural policies and failure of the international community to provide adequate aid (Devereux, 2001). By favouring exchange failures instead of production failures, this approach also downplays the significance of a decline in food availability in causing food insecurity and famine (Swift, 1993). For instance, the famine in Southern Africa in 2005 was caused by a decline in maize yield due to drought, and in Malawi resulted in serious food shortages

[2] The endowment set is defined as "the combinations of all resources legally owned by a person" (Osmani, 1993, p. 3). The entitlement set defines the optimum combinations of goods and services that a person chooses to pursue amongst the many options that their endowment set could provide (Osmani, 1993). The relationship between the endowment set and the entitlement set constitutes the entitlement mapping for a particular household (Osmani, 1993).

for nearly 4.7 million people (Devereux, 2006). A decline in food production could lead to higher food prices beyond the reach of poor and marginalised households.

Despite these criticisms, the entitlement approach offers a valuable lens through which we can assess how the various bundles that a household may be entitled to can be used to explain how they buffer against the negative impacts of drought on their livelihoods. In this thesis, the entitlement approach allowed a broad conceptualisation and exploration of the different capital assets that households and communities can access to reduce the adverse impacts of climate variability (particularly drought) on their livelihoods.

2.5.2 Sustainable livelihood approach

The sustainable livelihoods approach (SLA) was originally developed to assess poverty and builds on the entitlement approach (Sen, 1981). The SLA provides valuable insights into how people achieve their livelihoods outcomes by combining a range of capital assets to pursue different livelihoods activities (Bauman and Sinha, 2001). It has also been used to assess vulnerability. According to Chambers and Conway (1992, p. 7):

> "A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the [current and] next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long-term."

The SLA has been applied by development partners such as DfID, Oxfam and UNDP to assess the capacity of communities to withstand shocks associated with epidemics (Solesbury, 2003). Similarly, it is used to assess communities' capacities to withstand conflicts and other climate and non-climate stresses. Reid and Vogel (2006) used the SLA to identify a range of stressors that either reduce adaptive capacity or increase vulnerability to climate anomalies in South Africa. The livelihood approach argues that agriculture-dependent households may be able to reduce their overall vulnerability to climate variability and change by diversifying the strategies within their livelihood portfolios, or specialising to take advantage of a niche (Ellis, 1998; Fraser *et al.*, 2005).

The SLA has two major components; livelihoods and sustainability. Its main features are highlighted in Figure 2.1. Livelihood assets are the tangible resources and intangible assets (including claims and access) that people use to construct their livelihood outcomes. Livelihood strategies generally refer to the combination of activities that people embark on in order to achieve their livelihood outcomes (Chambers and Conway, 1992). Livelihood outcomes generally refer to the outputs (such as food security and more income) of the combination of livelihood activities (Chambers and Conway, 1992). In this regard, livelihood outcomes are greatly influenced by the vulnerability context, which refers to the external environment in which people or households exist (DfID, 1999). Within the SLA, vulnerability assessment considers the stresses, trends and seasonality that communities or local people may be exposed to and their capacity to withstand such stresses (Birkmann, 2006). Vulnerability also includes long-term trends such as migration, recurring seasonal changes, changes in the natural resource base as well as short-term changes such as conflict, illness and natural disasters (DfID, 2002). Hence, a vulnerable household, according to this research tradition, is one that is not able to sustain livelihood activities to cope with the shocks imposed by environmental shocks including climate variability (Adger, 2006).

Of particular importance in the SLA is the role of institutions and organisations that mediate access to resources and assets by households or people to pursue their livelihood outcomes within the vulnerability context (Figure 2.1). People's access to capital assets, their livelihood strategies and outcomes are governed by the prevailing policies as well as institutions (both formal and informal) (Yaro, 2004). The SLA also underscores the various interactions that govern households' or individuals' abilities to withstand shocks and stresses (Birkmann, 2006). What follows is an exploration of the links between access to livelihood capital assets and vulnerability to climate variability.

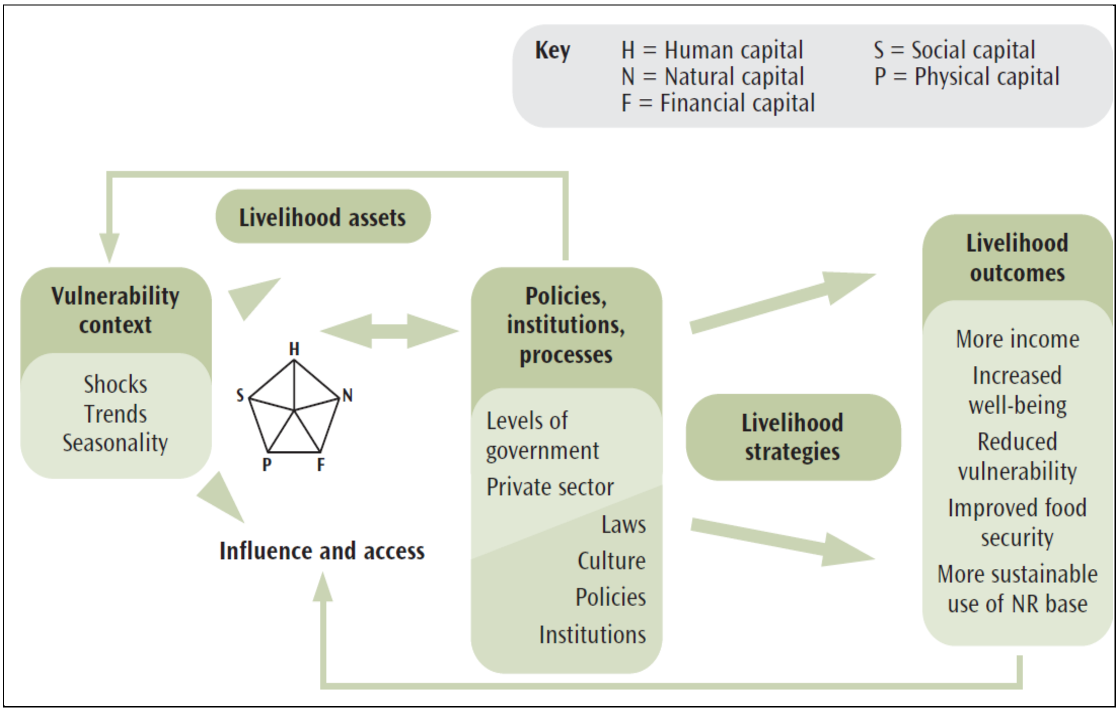

Figure 2.1: DfID Sustainable Livelihoods Framework
Source: DfID (1999)

2.5.2.1 Livelihoods capital assets and vulnerability to climate variability

It is vital to accentuate that one of the key ways in which people become vulnerable to climate variability is through vulnerability to their livelihoods. The SLA is premised on the principle that local communities possess various capabilities that need to be acknowledged. Essentially, the SLA can be used to explore how communities or people combine different capital endowments including tangible assets (e.g. material resources such as land) and intangible assets (e.g. educational levels, claims and access) that they have access to and control over to achieve their livelihoods objectives within the wider socio-politico-economic conditions (Yaro, 2004; Carney, 1998).

Traditionally, the SLA has been applied by considering the five livelihood capital assets – human, financial, physical, natural, and social – as well as their links to an overall vulnerability context, processes, institutions and policies and livelihood outcomes (Scoones, 1998). Human capital assets refer to the quality and quantity of labour. At the household level, this is reflected in the household size and composition and it is characterised by e.g. educational level, training and skills levels, and the health status of the household members (Rakodi, 1999; Elasha *et al.*, 2005). Natural capital assets consist of natural flows and stocks and other environmental resources that are useful for constructing livelihood outcomes (Scoones, 1998). They also include the quality and quantity of land, pasture, water, agro-ecological conditions such as soil quality, slope and topography of the land, forest resources (Elasha *et al.*, 2005) and that these resources may be improved or degraded by the actions of human beings. In most rural communities in many parts of SSA, natural capital in the form of land is a crucial asset for many livelihoods and therefore can greatly influence the other capital assets (Reale and Handmer, 2011). Financial capital includes income, savings, credit and other savings in liquid form (Scoones, 1998). It also includes remittances and easily disposable assets such as livestock and poultry (Hesselberg and Yaro, 2006; Elasha *et al.*, 2005).

Physical assets refer to non-land assets including infrastructure (e.g. markets, roads, electricity and irrigation facilities) (Elasha *et al.*, 2005). It also includes the type of housing, machinery and equipment (Scoones, 1998). Finally, social (including political) capital assets highlight the various rights and claims due to membership of recognised groups or associations (Elasha *et al.*, 2005). It includes networks and connectedness, social relations, as well as relationships of trust and reciprocity (Scoones, 1998). Social capital highlights the kind of rules, norms and reciprocity that shape social relations in a community. Farming communities draw on such capital assets to pursue their livelihood activities (mainly agriculture) (DfID, 1999). Social capital also includes membership of community-based organisations, professional unions, social or political networks, as well as reliance on family and friends for support in times of crisis (Scoones, 1998).

Several studies have applied the SLA (e.g. Reid and Vogel, 2006; Thomas *et al.*, 2007; Sallu *et al.*, 2010). Generally, these studies enhance our understanding of how communities or local people have responded to past environmental shocks by deploying the capital assets that they can command to withstand climatic shocks. Building on previous research on livelihoods diversification (Barrett *et al.*, 2001; Ellis, 1998; Paavola, 2008) and livelihood capital assets (Bebbington, 1999; Moser, 1998), this thesis adopts the SLA because an assessment of livelihoods offers the opportunity to highlight the various adaptations that might be available to determine how rural communities can cope with declining crop yields due to drought, and also how such declining yields can affect livelihoods (Ziervogel and Calder, 2003). In this thesis, the

SLA is used to frame how rural livelihoods, including food production systems, can become vulnerable through the identification of the various capital assets. These capital assets are employed by households to varying degrees to mitigate the effects posed by climate variability and change (see Eakin and Bojorquez-Tapia, 2008). Hence, accessibility to capital assets is a defining factor that greatly influences the ability of a household to cope with climate variability (Adger and Kelly, 1999).

2.5.2.2 Criticisms of the sustainable livelihood approach

Despite its utility and widespread use, the SLA has been criticised as an analytical tool in terms of its difficulty to address temporal dimensions, power dynamics as well as multiple scales. For example, it may only offer a snapshot of the vulnerability of the household or local people in a particular point in time and may not reflect the temporal changes associated with these shocks (Scoones, 2009; Toner, 2003). The vulnerability context as well as the policies and assets portfolio are dynamic and in constant state of flux. Therefore, there is the need to include a temporal dimension into the framework to strengthen its analytical value (Scoones, 2009).

The SLA has also been criticised for failing to explicitly include political capital (Scoones, 2009; Toner, 2003; Baumann, 2000). By failing to do this, it downplays the significance of power and politics in influencing the vulnerability of farming households to climate variability. Baumann and Sinha (2009) argued that the inclusion of political capital would greatly enhance the analytical value of the SLA. Moreover, the assessment of the possible impacts of transforming structures and processes on rural livelihoods is made difficult by the lack of inclusion of political capital.

Another shortcoming with the SLA is its failure to capture the dynamics of livelihoods analysis across multiple scales (Scoones, 2009). Whilst claiming to link micro to macro, Scoones (2009, p. 187) argues that such claim “is often more of an ambition than a reality.” For instance, the SLA fails to address wider global processes and how such processes impact livelihood activities and outcomes at the household level (Scoones, 2009). Globalisation affects households’ decision making and livelihood choices at the local level.

Although assets are mediated by various transforming structures including policies, practices and institutions that are embedded in the SLA, such transforming structures and processes have been deemed too general to be useful for empirical work (Birkmann, 2006). These transforming structures and processes are important in defining the various opportunities and constraints available to an individual or a particular household in pursuing their livelihoods outcomes (Yaro, 2004). The SLA has further been criticised for failing to acknowledge distributional issues (Swift *et al*., 2001). For instance, even though it highlights the importance of increasing the opportunities available for the poor to achieve their livelihoods, it fails to promote issues of equity (Yaro, 2004), which are central to coping and adapting to climate variability.

While offering a people-centred approach to the understanding of livelihood vulnerability and inequalities that confront various households and thereby shaping development objectives (van Dijk, 2011), the focus on the household has been deemed to result in methodological individualism (Du Toit, 2005). Moreover, livelihood assessments only superficially evaluate the capital assets that may be available to the households. For instance, livelihood analysis of a household may only provide assessment of the availability of natural capital to cope with drought but such assessments fail to provide valuable "insights into whether specific agro-ecosystems are likely to be sensitive to environmental change" (Fraser, 2007, p. 497). The SLA also fails to consider the physical and ecological environments (Adger, 2006). For instance, Scoones (2009) argues that the SLA fails to vigorously incorporate practices to deal with changes in environmental conditions. Finally, the SLA has been criticised for conceptualising poverty as a lack of capital assets instead of a lack of entitlements (van Dijk, 2011).

This thesis addressed these shortcomings by adopting a multi-scale climate change vulnerability assessment: mapping vulnerability at the national, regional, community and household levels. Concerns relating to temporal dimensions and power dynamics were taken into consideration in the choice of research methods. For instance, participatory methods were used to explore the temporal dimensions of livelihood vulnerability to climate change and variability as well as the influence of power relations within the study communities.

2.5.3 Assessing the temporal dimension of vulnerability

Several researchers (e.g. Brooks *et al.*, 2009; Fraser, 2007; Leach *et al.*, 2010) have used a combination of social and ecological theories to explain how food systems may be vulnerable to environmental (including climate) change. For instance, Fraser (2007) uses historical case studies to explain how food systems may be vulnerable to climate change and variability. First, he finds that changes in agro-ecological settings influence how agricultural productivity and food systems were sensitive to environmental changes. Second, sensitivity of people or communities depends to a greater extent on their ability to switch from agricultural-based livelihood systems to other livelihood strategies that depend less on the climate. Finally, he notes that local, regional and international institutions play a critical role in either reducing or exacerbating the vulnerability of communities to climate variability.

These observations led Fraser (2007) to propose that vulnerability of food systems to environmental change such as climate change can be assessed at the agro-ecosystem, community (livelihoods) and institutional levels. Hence, food systems within agro-ecosystems that are fragile with few livelihood options and social networks coupled with weak institutional arrangements are more likely to be vulnerable to environmental (climate) change (Fraser, 2006; 2007). Fraser's approach has been applied by several scholars (e.g. Dougill *et al.*, 2010; Fraser *et al.*, 2011; Sendzimir *et al.*, 2011) to assess the vulnerability of food systems or rural economies to environmental change. This thesis builds on this by combining livelihood theory with a temporal element through local level participatory approaches.

2.5.4 Quantitative indicator approach for vulnerability assessment

One typical approach for quantifying vulnerability to global climate change is to define a set of proxy indicators to assess vulnerability by estimating indices or averages for these selected indicators (Luers *et al.*, 2003; Gbetibouo *et al.*, 2010; Abson *et al.*, 2012). Thus, indicators may be defined as quantitative measures, usually single values, that are used to represent a characteristic of interest about a particular community, household or system (Hinkel, 2011). A desirable indicator seeks to simplify relevant information and should be quantifiable and measurable, making otherwise imperceptible phenomena visible (Moss *et al.*, 2001). Aggregating different indicators to represent a single unitless index to show the vulnerability of a particular region can be quite problematic (Sullivan and Meigh, 2005). This is even more challenging when such assessments are conducted across large spatial scales because the indicators used may behave differently in different regions (Eakin and Luers, 2006; Hinkel, 2011). In this regard, it is vital to have a clear and understandable methodology in the construction of indicators intended for use in vulnerability assessments (Gallopín, 1996; Abson *et al.*, 2012).

Considerable literature has been published on the use of quantitative indicator approaches to assess vulnerability to climate change and variability at the global scale (e.g. Fraser *et al.*, 2013; Ericksen *et al.*, 2011), regional scale (e.g. Abson *et al.*, 2012; Midgeley *et al.*, 2011), as well as national and district scales (e.g. O'Brien *et al.*, 2004a; Hahn *et al.*, 2009). This allows the comparison of the relative vulnerability of different nations, regions or districts to the adverse impacts of climate change and variability and provides valuable insights to policy makers and development partners regarding the current challenges confronting vulnerable groups and how these could be addressed through appropriate policy interventions (Hinkel, 2011; Abson *et al.*, 2012).

For instance, the South Pacific Applied Geosciences Commission developed the Environmental Vulnerability Index (EVI) to explore the vulnerability of the environment in Small Island Developing States (SIDS) to environmental shocks including climate change and variability (Kaly *et al.*, 2002; Kaly *et al.*, 1999). Whilst offering significant insights into the vulnerabilities, the EVI is not integrated enough as it does not include human systems (Barnett *et al.*, 2008). The authors of the EVI have assumed a clear correlation between environmental damage and loss of human welfare (i.e. human subsystem) in these countries (Kaly *et al.*, 1999). Nonetheless, the distinction between the human and natural environments may not exist in these small islands (Barnett *et al.*, 2008). The EVI also fails to understand the importance of placing the forces that influence vulnerability in the larger contexts (Barnett *et al.*, 2008). Changes in the environment that can result in the displacement of the population of these Island countries could not be entirely local. Many of the forces are likely to be regional and global because of globalisation (Barnett *et al.*, 2008) and therefore, treating countries as discrete units fails to acknowledge the fact that activities in one country could potentially create vulnerability in other countries (Morse and Fraser, 2005).

In another study, Moss *et al*. (2001) developed the Vulnerability-Resilience Indicator Prototype approach. They used indicators relating to settlement sensitivity, water availability, food security, human health sensitivity, ecosystem security and availability to explore the main environmental and socioeconomic factors that could influence the ability of these different groups to withstand the stresses imposed by climate change and variability in 38 countries. Moss *et al*. (2001) used adaptive capacity to capture both coping and adaptive capacity in their assessment. Moss *et al*.'s work has been criticised by several writers (Füssel, 2010; Eriksen and Kelly, 2007; Barnett *et al.*, 2008) who highlight that by not distinguishing between coping and adaptive capacity, this assessment fails to capture the main factors that might influence the way people use their livelihoods to manage risk associated with climate variability.

Brooks *et al.* (2005) used the indicator approach to assess climate vulnerability and adaptive capacity in different nations by examining the link between national-level socioeconomic data and climate-related mortality to highlight the main factors that correlate with past extreme weather events. They concluded that there was a strong correlation between 11 main socioeconomic indicators with aggregated mortality and that countries in SSA and those experiencing conflicts might be the most vulnerable. Whilst making significant contributions by identifying socioeconomic factors that may be lacking in typical quantitative crop modelling studies (e.g. Challinor *et al.*, 2010; Reidsma *et al.*, 2007; Lobell *et al.*, 2008), this study used only mortality rates as dependent variables and failed to account for other variables such as the size of the environmental anomaly that might have resulted in such mortality (Simelton *et al.*, 2009). Although the results of Brooks *et al*.'s study provides useful insights into the critical factors that could influence sensitivity of a particular country to climate variability, it should nonetheless be interpreted with caution as it provides an insufficient basis to inform policy (Simelton *et al.*, 2009).

O'Brien *et al.* (2004a) used a vulnerability index at the sub-national level to map the vulnerability of India's agriculture to what they termed as 'double exposure' (climate change and globalisation). O'Brien *et al*.'s work provided a useful method for mapping the vulnerability of various regions within a particular country that can aid policy makers in decision making. However, the study fails to adequately recognise the dynamic nature of the various components of vulnerability including exposure, sensitivity and adaptive capacity. For instance, basing the indicators of adaptive capacity on census data collected in 1991 might not have fully captured the temporal changes, a fact acknowledged by the authors.

Scholars such as Ericksen *et al.* (2011), Abson *et al.* (2012) and Midgeley *et al.* (2011) have also used a quantitative indicator approach to assess the vulnerability of climate variability at the regional and global scales. Ericksen *et al.* (2011) mapped hotspots of climate change and food insecurity in the tropics, conceptualising vulnerability as a function of exposure, sensitivity and coping capacity. The study revealed that the most vulnerable areas were characterised by high exposure and sensitivity to climate change coupled with low coping capacity (Ericksen *et al.*, 2011). Midgeley *et al.* (2011) conducted vulnerability assessments for Southern Africa to highlight "hotspots" of current and future (2050) vulnerability to climate change. This study showed that areas that relied significantly on rain-fed agriculture and characterised by high population growth were more vulnerable. Using Principal Component Analysis techniques, Abson *et al.* (2012) created spatially-explicit socio-ecological vulnerability maps for the Southern Africa Development Community. This study produced information-rich vulnerability maps that suggested that different parts of the region demonstrated different types of vulnerability to environmental (including climate) change. Such studies contribute to the understanding of the extent of vulnerability of different regions as well as enhancing the understanding of the various factors driving vulnerability.

Vulnerability assessments relying on census data at the national level could mask significant local level variability in terms of access to assets and entitlements (Eakin and Bojorquez-Tapia, 2008; Eriksen and Kelly, 2007) because of the problem of aggregation that makes particular poor regions seem less vulnerable than they really are (Morse and Fraser, 2005). This leads to loss of vital information relating to 'hotspots' of vulnerability at the local level (Eriksen and Kelly, 2007). The development of such vulnerability indices (which are based on pre-defined and theoretically-driven indicators) rarely acknowledges the participation of communities regarding what is perceived to influence vulnerability to climate variability at the local level (Thomas *et al.*, 2007). This thesis addresses these challenges by adopting a participatory approach to identify and unpack the extra information that can be obtained from village level vulnerability analysis that is lacking in these national and regional level assessments (see Chapters 5–7).

2.5.4.1 Usefulness and criticisms of the indicator approach

The previous section has demonstrated that the indicator approach is an extremely useful tool for monitoring and studying trends to guide policy formulation (Niemeijer, 2002). Equally important is the fact that the indicator approach is also applicable at any scale. Thus, this thesis uses a mixed-method approach that incorporates different aspects at different phases, creating a vulnerability index to identify key regions and districts in Ghana where food systems and livelihoods are most vulnerable to climate variability. This could guide policy formulation and aid relief interventions, helping to reduce the vulnerabilities of groups for whom vulnerability has been projected to increase due to extreme events associated with climate change and variability.

Notwithstanding, the use of an indicator approach has been highly contested by several writers (e.g. Barnett *et al.*, 2008; Eriksen and Kelly, 2007; Füssel, 2010). For example, there are serious contentious methodological issues regarding the selection, standardization and weighting of the various indicators (Eriksen and Kelly, 2007). These difficulties may be attributed to the complex and interconnected nature of the various processes that influence vulnerability (Barnett *et al.*, 2008; Füssel, 2010; Luers *et al.*, 2003). Another major weakness relates to the difficulties in simplifying the complex interactions that occur within a socio-ecological system to a single variable that may not be representative enough (Barnett *et al.*, 2008; Eakin and Luers, 2006).

Another drawback is that it is difficult to meaningfully compare results from vulnerability indices resulting from an indicator approach from one region to another, due to differences in the sets of variables used (Eriksen and Kelly, 2007; Cutter *et al.*, 2009). For example, Eriksen and Kelly (2007) examined five national level vulnerability studies that sought to compare the vulnerabilities of different countries based on the indicator approach. They observed that the results of these country-level vulnerability assessments could not be compared. Whilst three of the studies ranked country vulnerability, two studies displayed vulnerability of such countries in the form of maps instead of an explicit ranking. The review by Eriksen and Kelly (2007) observed that "a lack of clear theoretical and conceptual framework for the selection of indicators has hampered the robustness, transparency and policy relevance" of such studies (p. 496). They went on to highlight that even amongst the three studies that performed country vulnerability assessment by ranking, there were considerable differences regarding the selection and number of countries in such studies, making it difficult to compare findings (Eriksen and Kelly, 2007).

Using current proxy indicators based on existing vulnerability clearly poses a problem when considering future vulnerability to climate change since these indicators are dynamic (Vincent, 2007; Eriksen and Kelly, 2007; Leichenko and O'Brien, 2002) and can be considered descriptive rather than predictive. This is because this approach provides a snapshot in time of the vulnerability of particular household or community and does not capture temporal and spatial changes. To address the challenges relating to dynamic nature of vulnerability in quantitative assessments, this thesis employed local level participatory approaches including focus group discussions and oral narratives to capture how vulnerability has evolved within the local community. This provided a better understanding of how past livelihood activities have shaped vulnerability in such communities and offers useful insights into livelihood trajectories looking forward (Sallu *et al.*, 2010; Leach *et al.*, 2010). Other limitations of the indicator approach include the frequent lack of good information on the choice of appropriate variables that are required to establish the vulnerability index in a particular region (Eriksen and Kelly, 2007).

To overcome some of these deficiencies in the application of the indicator approach for vulnerability assessment, Eriksen and Kelly (2007) have suggested that the selection of indicators for the vulnerability assessment should be representative and robust. This relates to scale issues that are critical in vulnerability assessments (see also Barnett *et al.*, 2008). This thesis adopted a multi-scale approach by assessing vulnerability at the national and regional scales and drilling down to the community and household scales. Secondly, there should be a well-defined and transparent conceptual framework that recognises the multivariate character of the processes interacting to influence vulnerability. Consideration should be given to the selection and weighting of different variables as well as the weighting method applied for such assessments (Niemeijer, 2002). Thirdly, the processes that shape vulnerability in the vulnerability assessment should be verifiable. They argued that there should be an appropriate relationship between the theoretical assumptions and the empirical evidence. These points are taken into consideration in the research design (see Chapter 3).

These limitations have led various researchers to propose other frameworks for assessing the vulnerability of a system to climate change. For instance, the Luers *et al.* (2003) approach for quantifying vulnerability first assesses the sensitivity of a given system to different stresses and then identifies a threshold at which the system is considered to be damaged. They argued that "vulnerability assessment should shift away from attempting to quantify the vulnerability of a place and focus instead on assessing the vulnerability of selected variables of concern and to specific sets of stressors" (p. 257). In the next section, the concept of adaptation is explored with particular reference to some of the key strategies employed by households in SSA to adapt to climate variability (particularly drought).

2.6 The concept of adaptation to climate change and variability

Adaptation is not new to farming communities in SSA (Vogel, 2005). There have been many instances where societies have adapted to changes in climate, in order to survive, by altering settlements and agricultural patterns. However, climate change and its associated impacts add a new dimension to this challenge (Burton, 2009). Even though the international community has recognised the possible role that adaptation plays in climate change, the origins of adaptation have been traced to the natural sciences, namely population biology and evolutionary ecology (Winterhalder, 1980). The specific definition given to adaptation depends primarily on the researcher's discipline. For instance, in ecology, adaptation refers to the ability of an organism to adapt to changes in its environment (Martin *et al.*, 1996).

In the context of climate change research, various definitions of adaptation abound (Table 2.2). This thesis adopts Smith *et al.*'s (2000) definition of adaptation to climate change as the process by which stakeholders reduce the adverse effects of climate on their livelihoods. This conceptualisation allows a better understanding of how households and communities use their adaptive capacities and various assets in reducing the adverse impacts of climate variability on food systems and livelihoods. This will help in assessing how such households and communities could be assisted by various stakeholders to withstand climatic stresses.

Even though agriculture is one of the most widely studied sectors with respect to the impacts of climate change, until recently, efforts have neglected the possible role of adaptation by farmers (Schipper and Burton, 2009). Prior to 1992 the term adaptation was rarely used in relation to climate change (Schipper and Burton, 2009). The focus of the international community was on mitigation, which involves reducing the emissions of greenhouse gases and increasing carbon sinks, thereby slowing the rate of global climate change (IPCC, 2007). The attention of the international community was on setting targets and schedules for emissions reductions to slow down the rate of global warming (Burton, 2009). Indeed, Stringer *et al*. (2009) stress that "…proponents of adaptation were viewed as rather defeatist and were thought to demonstrate a lack of faith in countries' abilities to limit emissions" (p. 750). However, the world will likely continue to warm at a significant rate for many decades whatever targets may be agreed to reduce emission (IPCC, 2007). Therefore, adaptation is necessary in order to reduce the adverse impacts of climate change and variability on agriculture (Yohe, 2000). Failing to implement appropriate adaptation strategies for the most vulnerable groups, could lead to serious problems including significant deprivation, social disruption and population displacement, and even morbidity and mortality (Downing *et al.*, 1997).

Several authors are of the opinion that recent international efforts seeking solutions to the menace of climate change and variability have recognised the role of adaptation as a policy option (Ford, 2007; Pielke *et al.*, 2007; Smit and Skinner, 2002). For instance, Smit and Skinner (2002) highlight that adaptation as a response to climate change has been covered extensively in the Fourth Assessment Report by the IPCC, while Article 10 of the Kyoto Protocol and Article 4.1b of the United Nations Framework Convention on Climate Change are explicit in emphasising the possible role of adaptation to reduce the adverse impacts of climate change (UN, 1992).

Table 2.2: Some definitions of adaptation in the climate change literature

Author(s)	Definitions
Pielke (1998, p. 159)	Adaptation involves "adjustments in individual groups and institutional behaviour in order to reduce society's vulnerability to climate."
Burton *et al.* (2002)	Adaptation is the capacity of a system or community to adjust to a particular change in order to reduce the impacts of that change.
Brooks (2003)	Adaptation is the process of adjusting the attributes of system to be able to withstand external shocks.
Smit and Pilifosova (2001, p. 881)	Adaptation refers to "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts."
Smith *et al.* (2000)	Adaptation is the process by which stakeholders reduce the adverse effects of climate on their livelihoods.

Central to the understanding of climate adaptation in agricultural systems and rural livelihoods are coping capacity and adaptive capacity. Adaptive capacity and coping capacity are widely used terms in climate adaptation literature (Yohe and Tol, 2002; Engle, 2011) (see Section 2.4.4 for details on adaptive and coping capacity). Several authors (e.g. Nielsen and Reenberg, 2010a; Jones and Boyd, 2011) recognise that adaptive capacity and coping strategies are situated within wider socio-cultural and religious processes occurring within such communities. Therefore, efforts should be made by policy makers to take cognisance of such processes and factors when designing climate adaptation strategies aimed at enhancing the capacities of rural communities to withstand the negative impacts of climate variability on their livelihoods.

2.6.1 Types of adaptation

Adaptation to climate change in agriculture may be autonomous or planned (Dinar *et al.*, 2008; Smith *et al.*, 2000). Autonomous adaptations are coping strategies which are mostly temporary and reactive in nature and can be implemented by individuals, agents and institutions (Dinar *et al.*, 2008). For instance, in response to a changing precipitation pattern, a farmer may decide to change the crops or use different harvest and planting dates (FAO, 2007). Hence, the effectiveness of autonomous adaptation strategies depends on the availability and accessibility of resources to cope with sudden climate changes (Dinar *et al.*, 2008). In contrast, "planned adaptation measures are conscious policy options or response strategies, often multi-sectorial in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations" (FAO, 2007, p. 5). Indeed, planned adaptation (also called anticipatory adaptation) seeks to address future climate stresses and could be based on predicted future climate adverse impacts or past experiences (Fankhauser *et al.*, 1999). While there is a distinction between planned and autonomous (reactive) adaptation, in practice the line between these two is blurred (Fisher *et al.*, 2010). This thesis explores both autonomous and planned adaptation strategies employed by farming households and communities to reduce the adverse impacts of climate variability on their livelihoods. For instance, planting drought-tolerant and early maturing varieties of crops are examples of planned adaptation while resorting to a reduction in food consumption by the households because of climate related food insecurity could be considered as autonomous adaptation strategy (see Chapter 6).

Many researchers recognise that climate change is generally a problem but that adaptation can reduce the impacts of climate change on agriculture (Mitchell and Maxwell, 2010; FAO, 2007). Most agricultural systems, like many other ecosystems, have some level of inherent adaptive capacity, but this may be compromised because of the rapid rate of climate change and variability (Ziervogel *et al.*, 2008). This becomes even more serious because secondary changes induced by climate change have the potential to constrain the capability of people and ecosystems to cope with the impacts of climate change and variability. It is for this reason that the IPCC encourages 'planned adaptation': deliberate steps aimed at creating the capacity to cope with the impacts of climate change (IPCC, 2007).

The IPCC also makes a distinction between private and public adaptations. McCarthy *et al.* (2001) define private adaptation as those adaptations that are undertaken by individuals or households whilst public adaptation is initiated and implemented by the government and its agents. Whilst private adaptations deliver benefits exclusive to the individuals or households that take those decisions, public adaptations target collective needs (Dinar et al., 2008). This thesis examines both private adaptations that are taken by households and public adaptations that are initiated by the government and its agents at the national, regional and community levels.

2.6.2 Scale of adaptation to climate change and variability

A raft of typologies has been proposed for the study of agricultural adaptation to climate change. The terms “scales” and “levels” are used interchangeably. Gibson *et al.* (2000, p. 218) defined scale as “the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon, and levels as the units of analysis that are located at different positions on a scale.” Hence, spatial scale can be divided into different levels, whilst temporal scale can be divided into different time frames (Gibson *et al.,* 2000).

Smit and Skinner (2002) identified four major categories of agricultural adaptation pathways: “(1) technological developments, (2) government programmes and insurance, (3) farm production practices, and (4) farm financial management” (p. 95). Categories 1 and 2 involve strategies pursued by public institutions and organisations (Smit and Skinner 2002). Examples of Category 1 pathways include the development of new crop varieties, development of early warning systems that provide weather predictions and seasonal forecasts and the development of irrigation techniques to address moisture deficiencies. Examples of Category 2 pathways include agricultural subsidy support programmes, the development of private insurance to reduce climate related risk, and the development of policies to influence farm-level production. On the contrary, Categories 3 and 4 are undertaken at the level of the individual farmer or farmers’ group. Examples of Category 3 pathways include diversification of crop types/varieties and livestock types, changing land use practices to address environmental variations and changing timing of farm operations such as planting and harvesting dates (Smit and Skinner, 2002). Using crop insurance, participation in appropriate income stabilisation programmes and diversification of household income are examples of Category 4 pathways.

In terms of scale of agricultural adaptation, Kandlikar and Risbey (2000) differentiate farm-level adaptation from regional and national level adaptation. Regional- and national-level adaptation involve changes in infrastructure as well as support systems whereas farm-level adaptation covers the range of farm management practices undertaken at the farm or field level by the farmer in an attempt to moderate the adverse impacts of climate variability (Kandlikar and Risbey, 2000). Adaptation may also be characterised by timing (reactive or anticipatory), duration (short or long term), as well as its spatial occurrence (i.e. whether it is localised or widespread) (Smit *et al.*, 1999). The success of agricultural adaptation to climate variability should not be measured only by economic outputs in terms of yields but also by ethical considerations relating to distributional and social issues such as equity and fairness (Kandlikar and Risbey, 2000). This thesis adopts a multi-scale approach by exploring adaptation measures at the national, regional, community and household scales.

2.6.3 Climate adaptation strategies in Sub-Saharan Africa

Several authors have documented adaptation measures that are initiated and implemented by households across SSA to mitigate the adverse impacts of climate change and variability on their livelihoods (Thomas *et al.*, 2007; Paavola, 2008; Cooper *et al.*, 2008). Rural households in dryland farming systems simultaneously respond to other social-economic and political stressors in addition to climate change, thereby making it difficult to assess the impacts of climate variability in adaptation responses (Nielsen and Reenberg, 2010b). At the micro-level, the major adaptation measures that have been employed by households in SSA include, but are not limited to, livelihood diversification, crop diversification, migration, planting early maturing varieties of crops, planting drought-tolerant crops, selling farm labour and using agro-forestry practices (e.g. Paavola, 2008; Cooper *et al.*, 2008; Stringer *et al.*, 2009).

Considerable literature has been published on the use of livelihood diversification as an adaptation strategy to reduce the production risk associated with climate variability across many parts of Africa as shown in Table 2.3 (Paavola, 2008; Ellis, 1998; Osbahr *et al.*, 2010). Livelihood diversification has also been reported elsewhere including India (Datta and Singh, 2011), Sri Lanka (Esham and Garforth, 2012) and Jamaica (Campbell *et al.*, 2011). Households may be able to reduce their overall vulnerability to climate variability by diversifying the strategies pursued within their livelihood portfolios or specialising to take advantage of a niche (Ellis, 1998; Fraser *et al.*, 2005). The essence of livelihood diversification is to create portfolios of activities that have varying risks associated with them (Reardon and Vosti, 1995; Fraser *et al.*, 2005). For example, Fraser *et al.* (2005) demonstrate that *Modern Portfolio Theory* can be used to reduce investment risks in order to allow investors to achieve higher returns on their investments. Similarly, by diversifying their livelihood portfolio (i.e. augmenting the number of livelihood activities and/or strategies pursued), the smallholder farmer will inevitably be reducing the risks of an overall adverse livelihood outcome.

Table 2.3: Livelihood diversification as climate adaptation in sub-Saharan Africa

Country	**Context**	**Author(s)**
Burkina Faso	Farming households are using various ways to diversify their income as a major adaptation strategy in the Mossi plateau.	Barrett *et al.* (2001).
Ghana	Households are increasingly diversifying their livelihoods sources as coping measure to mitigate the negative effects of climate variability.	Codjoe *et al.*, (2011).
Namibia	Households in Omusati are diversifying their livelihoods into off-farm livelihoods activities to cope with climate change.	Newsham and Thomas (2011).
Nigeria	Households are using various forms of livelihood diversifications as well as using different varieties and cultivars of millet and sorghum to cope with drought.	Mortimore and Adams (2001); ,Dabi *et al.* (2008).
South Africa	Households employ different strategies including commercialising their livelihoods and using social networks to reduce the impacts associated with climate uncertainties.	Thomas *et al.*, (2007).
Tanzania	Households in the Morogoro region are increasingly relying on livelihood diversification to cope with the adverse impacts of rainfall variability.	Paavola (2008).

However, other researchers (e.g. Ellis, 1999; Barrett and Swallow, 2005; Eriksen *et al.*, 2005) have highlighted the potential drawbacks with livelihood diversification as an adaptation strategy. For instance, it has been argued that specialising in one livelihood activity could yield higher economic returns than the engagement of the household in a number of livelihood activities (Eriksen *et al.*, 2005). Further, Bryceson (2002) challenged the assumed positive relationship between livelihood diversification and poverty reduction, and by extension, climate adaptation. Another potential drawback with livelihood diversification is the loss of productive labour. For example, migration of male labour due to livelihood diversification into distant markets could result in depletion of the local productive labour force (Ellis, 1999), that could consequently reduce economic returns.

In most parts of Africa, temporary migration has been used as both reactive and anticipatory response to drought-induced food insecurity (Tyson *et al.*, 2002; Meze-Hausken, 2000). A study by Tyson *et al.* (2002) highlights that temporary migration is not an uncommon adaptation strategy in response to changing weather patterns (particularly drought) within subtropical Africa. In another study, Dabi *et al.* (2008) observed that labour migration was one of the principal strategies indicated by rural households in northern Nigeria as both a past and present climate adaptation strategy. In Ghana, a report by Rademacher-Schulz and Mahama (2012) shows that households in the Nadowli district migrate because of food insecurity linked closely to climate variability. People who solely depend on rain-fed agriculture for their livelihoods (as in many SSA countries) may have their livelihood activities jeopardised by increasing droughts as a result of climate change. Hence, such households may have few options other than to migrate to find alternative livelihoods elsewhere. This is even more serious in situations where such households cannot switch their livelihood activities in their present communities.

The importance of agro-forestry practices as a climate adaptation strategy has been widely emphasised in many parts of the world (Mcneely and Schroth, 2006; Kebebew and Urgessa, 2011; Altieri and Nicholls, 2005). For instance, the integration of agricultural systems with trees on the same piece of land can ensure the complementary use of environmental resources that can enhance productivity (Altieri and Nicholls, 2005). In east and central Africa regions, agro-forestry provides opportunity for low-income farmers to enhance their livelihoods by selling the small timbers, medicines and food (Jama *et al.*, 2006; Kebebew and Urgessa, 2011). Agro-forestry systems provide both mitigation and adaptation measures to the menace of climate change (Nyong *et al.*, 2007). In drought prone regions, agro-forestry practices have the potential to improve the microclimate through the modification of temperature which consequently reduces heat stress and evapotranspiration and can yield positive benefits for food production (Jose *et al.*, 2004).

Households also depend on non-timber forest products such as snails and mushrooms to cope with climate variability and ensure sufficient food (e.g. Pouliot and Treue, 2013; Ziervogel *et al.*, 2006). The extent of reliance of farming households in Malawi on these forest resources is greatly influenced by the characteristics of the households

(Fisher *et al.*, 2010). Households that were headed by people with at least primary education with good human capital were less likely to rely on non-timber forest products to cope with crop failure due to climate variability. Deressa *et al*. (2009) observed that planting different crop varieties, tree planting and changing the timing of planting were some of the key adaptation strategies used by farmers in Ethiopia in response to climate variability.

Though at early developmental stages, the use of weather-based index insurance schemes has also been explored in many countries in Africa including Malawi (Hess and Syroka, 2005) and Ethiopia (Hess and Im, 2007). The key principle underlying weather-based index insurance is that the government through its principal agencies provide insurance against specific climate events like droughts that could destroy crops (Hazell and Hess, 2010; Linnerooth-Bayer and Mechler, 2006). These events could be recorded at local weather stations or at the regional level (Hess and Im, 2007; Linnerooth-Bayer and Mechler, 2006). Hence, farmers who purchase this weather-based insurance are given specific payments to offset losses incurred from such droughts. The climate events should have a significant impact on crop yield and the index should be clearly defined, specifying the threshold of drought events that will warrant payment of a specific amount to farmers (Hazell and Hess, 2010; Chantarat *et al.*, 2007). Farmers within the same locality pay the same premium and are tied to the same local weather station. Weather-based insurance schemes hold great prospects for climate adaptation in many parts of Africa. Such schemes could provide significant solutions to reduce climate vulnerability, especially when combined with existing practices and local indigenous knowledge.

It is significant to emphasise that most of the adaptation measures highlighted above are used by farmers in SSA as risk spreading measures to reduce the negative impacts of climate variability, but that they fail to take advantage of the opportunities presented in relatively good farming seasons (Cooper *et al*., 2008). Such measures are more coping strategies (rather than adaptations) that reduce present vulnerabilities without necessarily accounting for future climate change. In this regard, for adaptation strategies to be effective and successful, they should reduce present and future vulnerabilities to climate change as well as increasing resilience (Huq *et al.*, 2004; Van Aalst *et al*., 2008). Climate adaptations should seek to maximise the potential benefits that can be derived from a more resilient society (Mitchell and Maxwell, 2010). Indeed, if adaptation strategies to climate change are managed properly, many environmental benefits can be derived from them (FAO, 2007). In this regard, adaptation practices should be compatible with national developmental agendas (Mitchell and Maxwell, 2010) and be mainstreamed into developmental programmes (Huq *et al.*, 2004).

The implementation of the various adaptation strategies may be impeded by several barriers. Barriers are defined as factors or obstacles that reduce the effectiveness of adaptation strategies (Moser and Ekstrom, 2010). In the literature, the term "barriers" has been used interchangeably with "limits to adaptation". In the IPCC's fourth assessment report, limits are defined as "conditions or factors that render adaptation ineffective as a response to climate change and are largely insurmountable" (Adger *et al.*, 2007, p. 733). Limits are therefore unsurpassable. Several studies have documented that agricultural adaptation to climate change and variability could be impeded by economic, cultural and social barriers including land tenure insecurity (Jones and Boyd, 2011; Esham and Garforth, 2012; Nielsen and Reenberg, 2010a).

Whilst making useful contributions by enhancing understanding of the adaptive measures that have been used by households in SSA and more widely to cope with and adapt to climate change and variability, most of these studies fail to highlight the behavioural and socioeconomic factors that may influence the choice of these adaptive measures, although recent progress in this area is acknowledged (Below *et al.*, 2012; Deressa *et al.*, 2009; Hisali *et al.*, 2011). This has resulted in the development of one size fit all adaptation strategies that may not respond to the crisis faced by certain social classes. Hence, there is the need to carefully explore how farmers' choice of adaptation measures is influenced by socioeconomic as well as political characteristics so as to enable region-specific adaptation policies to be designed and implemented. By adopting a starting-point interpretation approach of vulnerability, this thesis seeks to explore appropriate adaptation measures that may be used to reduce the vulnerability of households to climatic stresses.

2.7 Synthesis and conclusions

This literature review has demonstrated that increasing temperatures and rainfall varaibility associated with climate change and variability could have a devastating effect on livelihoods as well as all the four components of food security (availability, accessibility, utilisation and stability) in SSA (Boko *et al.*, 2007). However, these impacts will vary spatially. Hence, understanding the complexity of climate impacts on agricultural systems requires further investigation through more detailed assessments of key regions in West Africa.

Although vulnerability as a concept is difficult to measure and describe, this review has provided useful insights into vulnerability assessments by establishing that several authors have proposed different theoretical and conceptual frameworks to assess the vulnerability of food systems and that such frameworks could be considered in relation to climate change and variability. These vulnerability assessments may be used to identify vulnerable groups within a particular geographical area and can inform policy regarding resource allocation in such areas.

Whilst contributing to the understanding of the factors that may cause vulnerability, many of these studies (e.g. Abson *et al.*, 2012; Ericksen *et al.*, 2011) use national level data and indicators that have been selected somewhat subjectively from the literature. Although such national-level theoretically-driven vulnerability assessments provide a strong foundation from which more detailed work can take place, their relevance at the local level may be limited. Given the inadequacy of such national and regional-level assessments to inform policy at the local level, this thesis seeks to use empirical data based on the factors that local farmers perceive to influence (drive) vulnerability to climate variability.

In addition, most of the vulnerability assessments have been conducted at specific scales–notably at the global scale (Action-Aid., 2011), regional scale (e.g. Midgeley *et al.*, 2011) and national scale (e.g. Hahn *et al.*, 2009). Other assessments have been undertaken at the household level without considering the wider processes operating at the societal and regional levels that can influence the vulnerability of people at households. Whilst these allowed comparison of the relative vulnerability of different nations and regions to the adverse impacts of climate change, they failed to consider the multi-scale nature of vulnerability by concentrating on only one scale. Global climate change produces cross-scale interactions that provide impacts at different geographical scales, which are not discrete but on a continuum (Cash *et al.*, 2006). Adopting a multi-scale approach to drought vulnerability assessments provides a significantly richer understanding of the different dimensions of the problem through its exploration across scales. By using a multi-scale approach (i.e. national, regional, village and households), as widely called for in the vulnerability literature (Cash *et al.*, 2006; Gibson *et al.*, 2000; Wilbanks, 2002), this thesis avoids the danger of narrowly focusing on one scale of climate variability problems.

Though sub-Saharan Africa is projected to be severely affected by climate change, specific case studies in this region highlighting the extent of vulnerability of food production systems and livelihoods to climate change and variability are lacking. This knowledge gap hampers proper understanding of the drivers and barriers of vulnerability of food production systems and livelihoods in this region to climate change and variability. For instance, the specific adaptive capacity that farming communities in this region might have is often ignored in vulnerability assessments. There is, therefore, the need for specific case study research to be conducted to clearly understand the extent of vulnerability of food production systems and livelihoods in this region to climate change and variability. This thesis addresses these research gaps by integrating different participatory methods and ecological surveys to assess the extent of food production system and agricultural livelihoods' vulnerability to climate variability in Ghana.

CHAPTER 3

STUDY AREA, RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter describes the study country (Ghana) highlighting the nature of its farming and land tenure system. This chapter also describes the research design and the methods used to collect data to achieve the objectives and address key gaps in the literature. It explains how the farming communities in the study area were selected and provides a description of these communities. The chapter highlights the sampling approach and describes how the qualitative and quantitative data were collected and analysed. The relevance of participatory methods for this thesis is also explored. The strengths and limitations of the various research methods used for data collection are then discussed later. Finally, issues relating to positionality and ethical considerations are explored in this chapter.

3.2 Study area

Ghana (Figure 3.1) is situated on the Atlantic Coast of West Africa between latitudes 4.5^{o}N and 11.5^{o}N and longitudes 3.5^{o}W and 1.3^{o}E and shares borders with Cote d'Ivoire to the West, Togo to the East, and Burkina Faso to the North (EPA, 2001). Ghana is divided into 10 administrative regions within six agro-ecological zones, which reflect the dominant climatic conditions and vegetation (Figure 3.2 and Table 3.1). The agro-ecological zones are rainforest, coastal savannah, semi-deciduous forest, transitional zone, Guinea savannah and Sudan savannah zones. There are two distinct rainfall regimes in southern Ghana, with a uni-modal rainfall pattern in northern Ghana including the Sudan and Guinea savannah zones. Average annual rainfall ranges between 800 mm and 2400 mm, generally decreasing from south to north (EPA, 2001). Temperatures in most parts of the country are high, with a mean annual temperature of above 24^{o}C (EPA, 2001).

The Population and Housing Census conducted in 2010 estimated the population to be 24.6 million, which represents an increase of 30% in population of the country from the 2000 census data (GSS, 2011). Ghana has a total land area of 238, 583,900 ha, of which 13,628,179 ha (representing 57%) is agricultural land. In 2000, the total area under agricultural cultivation was estimated at 5,808,600 ha, with only 11,000 ha being under irrigation (MoFA, 2007).

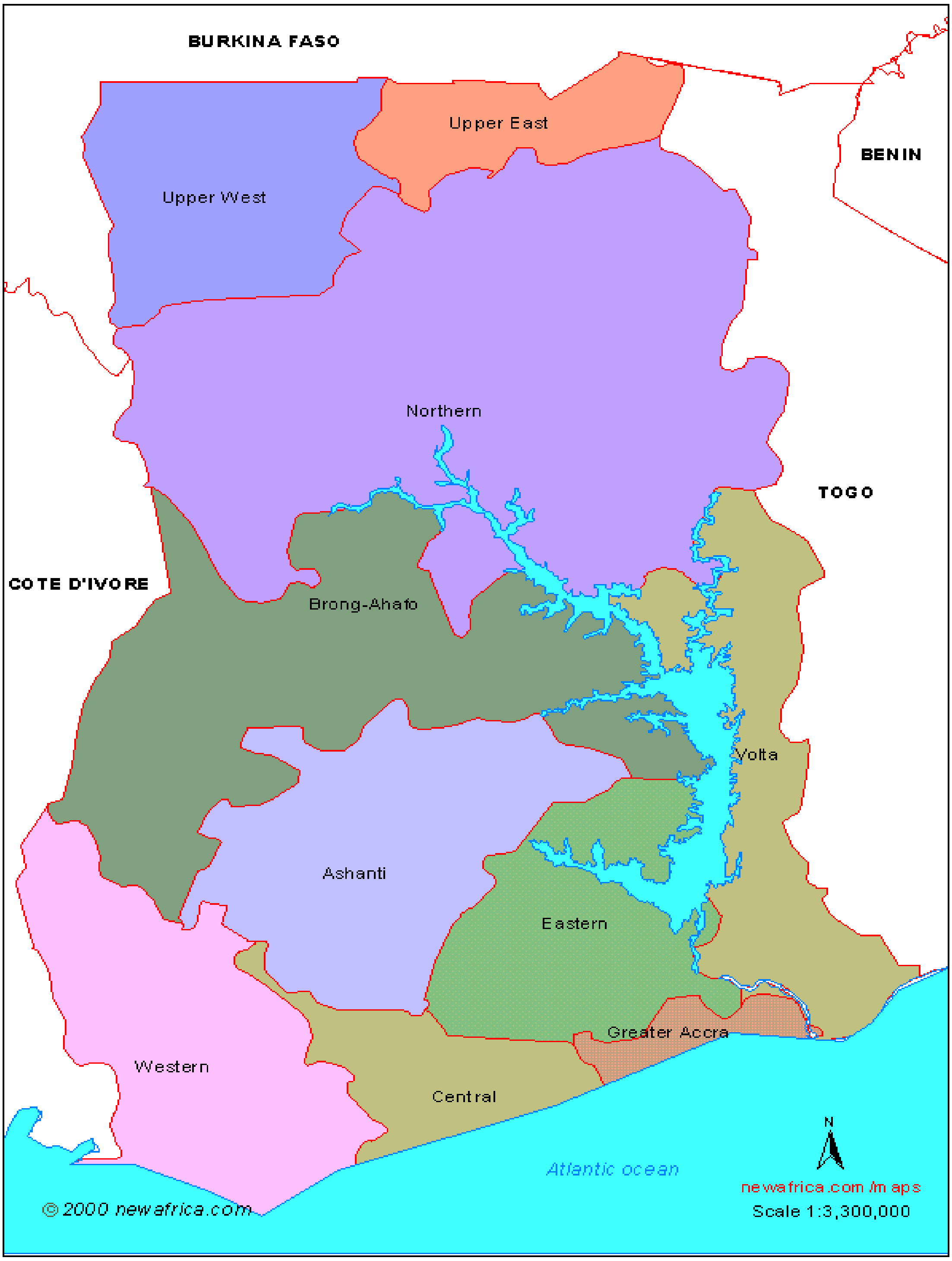

Figure 3.1: Ghana showing administrative regions
Source: Ghana Homepage (2010)

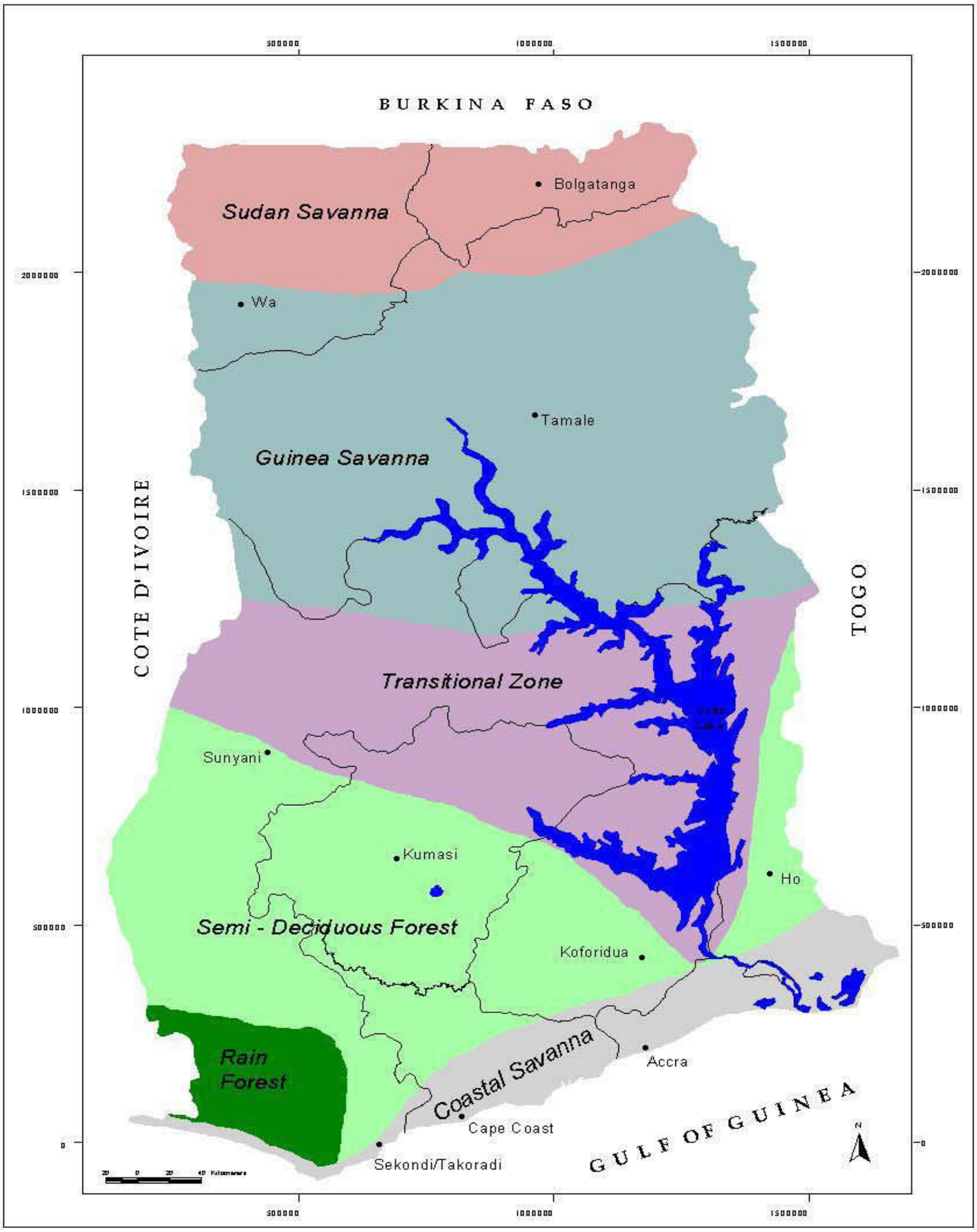

Figure 3.2: Ghana showing different agro-ecological zones.
Source: Benneh and Agyapong (1990)

In spite of this vast arable land area, Ghana is able to produce only "51% of its cereal needs, 60% of fish requirements, 50% of meat and less than 30% of the raw materials needed for agro-based industries" (MoFA, 2007, p. 5). The production of root, tuber and vegetable crops is highly variable depending on the vagaries of the weather (Sagoe, 2008). Ghana is unable to produce enough to feed its citizens due to the fact that a significant proportion of agricultural land has poor soil properties making both crop and livestock productivity very low (MoFA, 2007). It is estimated that 80% of agricultural production in Ghana is produced by smallholder farmers, who use rudimentary technology such as hoes and cutlasses (MoFA, 2007).

Crops that are socioeconomically important include maize, rice, sorghum, millet, cassava, yam, cowpea and plantain. Maize is considered the most important food crop in terms of hectarage under cultivation with an estimated 63% of farmers cultivating it. It is also widely consumed as a staple almost in every part of the country (Morris *et al.*, 1999). Cassava, yam and plantain are mostly cultivated by farmers in costal savannah and transitional agro-ecological zones (Figure 3.2). Sorghum and millet are predominantly grown in the Guinea and Sudan savannah zones. Climate change related problems such as drought and floods have often resulted in severe food insecurity (MoFA, 2007).

Table 3.1: Typical rainfall characteristics of agro-ecological zones in Ghana

Agro-ecological zone	Annual rainfall (Mean)	Range (mm)	Major rainy season	Minor rainy season
Sudan savannah	1000	No data	May–Sept	No data
Guinea savannah	1000	800–1200	May–Sept	No data
Transitional zone	1300	1100–1400	Mar–July	Sept–Oct
Semi-deciduous forest	1500	1200–1600	Mar–July	Sept–Nov
Rain forest zone	2200	800–2800	Mar–July	Sept–Nov
Costal savannah	800	600–1200	Mar–July	Sept–Oct

Source: Data adapted from the Ghana Meteorological Agency (GMet), Accra, Ghana

Because indigenous land tenure system is critical in disposing households to climate vulnerability, the next section briefly describes the nature of land tenure in the study area. Chapters 5 and 7 provide further insights into how land tenure influences the vulnerability of farming households in the study area.

3.3 Land tenure system in the study area

Land tenure defines access to land resources and considers the ways in which land is held or accessed (Bugri, 2008). In Ghana, like in most parts of Africa, land resources are controlled under complex customary systems, which are managed by a set of social norms and cultural rules (Yaro, 2010). Prior to colonisation, land ownership, rights and tenure in Ghana were customarily controlled, invested and administered under the spiritual or traditional head of a clan or a family (Aidoo, 1996). During colonisation, the land tenure system included both the customary system and the British conveyance system. The structural adjustment programmes and economic reforms of the World Bank and the International Monetary Fund embarked on by the government of Ghana in the late 1980s included institutional reforms that reverted control over land back to the traditional authorities (Yaro, 2010).

The 1992 Constitution of the Republic of Ghana recognises two forms of tenure systems – public and customary. Public lands are acquired through the invocation of legislation according to the Lands Commission Act of 1994 (Act 458) and invested in the President of the Republic in trust for the people of Ghana (MLF, 1999). Customary land is held and administered by the traditional or spiritual head of the family with state agencies such as the Lands Commission of Ghana, providing services for land transaction (Yaro, 2010). Customary land tenure systems are recognised and observed as an institution governed by customary law (Gough and Yankson, 2000). In accordance with article 258 of the 1992 Constitution of the Republic of Ghana, the Land Commission Act of 1994 (Act 483) stipulates that 78% of all land is held under customary system. Of the remaining 22%, 20% is held for the government for developmental projects whilst 2% is held in a dual ownership between the government and customary owners (MLF, 2003).

In Ghana, access to land for farming and other developmental projects by individuals is mainly through the traditional customary land ownership system (Kasanga, 2001). Members of a particular clan or community can acquire land for farming and other developmental ventures preceded with the presentation of customary gifts to the traditional or spiritual leader (Kasanga, 2001). However, people from outside the community do not have rights to communal land and may acquire land for farming by entering into a contractual agreement with the chief or the traditional head for a specific period of time (Kasanga *et al.*, 1996). The belief underpinning the customary land system is that land is an ancestral trust and should, therefore, be utilised judiciously in order not to jeopardise the chances of the generations unborn to use such resources (Gough and Yankson, 2000). For this reason land rights are held as leasehold and not freehold in Ghana.

Ownership of customary land differs remarkably across the different parts of the country. Within Ghana, inheritance of communal land is based on the system of property inheritance, which is matrilineal in southern Ghana and patrilineal in northern Ghana. In southern Ghana, ownership of land is not gendered, meaning that both male and female of a particular clan can access and own land. However, in northern Ghana (i.e. Northern, Upper West and Upper East regions) there are complex land tenure issues and land ownership is gendered. In these regions, it is the Tendana[3] who represents his people that owns 'alloidal'[4] rights to all lands in the community and who is therefore entitled, under the customary system, to grant usufruct rights to families and individuals within the community (Yaro, 2010). The Tendana holds alloidal rights on the behalf of the community and for that matter when individual's usufruct rights to a particular land is terminated the land reverts to the Tendana (Kasanga *et al.*, 1996).

In northern Ghana, land inheritance is through the male heir, and female right of usufruct is not recognised under the customary law (Yaro, 2010). The cultural discrimination against females relating to land ownership increases women's vulnerability and food insecurity. Agricultural activities in most parts of Africa are beset with various challenges including lack of markets, poor rainfall, lack of financial resources, and lack of infrastructure. However, unequal access to land and its associated land insecurity have been identified as one of the most important factors that negatively impact on the livelihoods of smallholder farmers in Africa (Toulmin and Quan, 2000). These issues are explored in detailed in Chapters 5 and 7.

3.4 Research design and approach

The research design developed to address the thesis objectives used an integrated range of methods including quantitative assessments of climate and crop yield data; participatory methods to assess indicators of adaptive capacity; expert interviews to

[3] The *Tendana* is usually a patrilineal descendent of the original family that first settled in the community but occasionally, may be chosen by a soothsayer (Yaro, 2010).
[4] The term alloidal refers to "land free from the tenurial rights of a feudal overlord. It refers to the fundamental land rights holder" (Kasanga *et al.*, 1996, p. 4).

assess institutional capabilities; and ecological surveys to assess environmental resilience in the study communities. The research design develops and applies a multi-scale integrated suite of analysis approaches for climate change vulnerability assessment, adaptation strategies and policy support. Data collection was divided into three interlinked phases throughout the 2 years of data collection and analysis. Figure 3.3 shows the research design and how the various methods are linked to the research objectives.

- The first phase is sub-divided into two stages. Stage 1a) involved using a quantitative vulnerability assessment to identify resilient and vulnerable regions and districts in Ghana. Stage 1b) involved the selection of specific resilient and vulnerable farming communities within the resilient and vulnerable districts identified in Stage 1a) through expert and stakeholder interviews through an exploratory fieldwork.
- The second phase (i.e. main fieldwork) is further sub-divided into three stages. Stage 2a) involved the use of participatory and quantitative methods and ecological surveys to characterise and explain the nature of resilient and vulnerable farming communities identified in phase 1 based on (i) farm (agro-ecosystems); (ii) community or livelihoods; (iii) socioeconomic; and (iv) institutional factors (Figure 3.3). Stage 2b) used participatory methods to determine adaptation strategies used to manage climate variability in study communities. Stage 2c) used participatory methods to identify barriers to adaptation strategies in the study communities.
- The third phase involved the use of expert and stakeholder interviews, as well as policy analysis, to assess institutional capabilities and policy arrangements at the local, regional and national levels (i.e. supplementary fieldwork). This phase also involved the use of oral history narratives with outlier housheolds to explore temporal dynamics of food production and livelihhod systems' vulnerability to environmental (including climate) change.

Though they have different epistemological and ontological backgrounds, qualitative and quantitative methods can be combined and this allowed deepening of understanding through cross-validation of data (Bryman and Bell, 2007). Qualitative methods are flexible and allow a deeper and better understanding of the extent of vulnerability of households and communities to climate change and variability (Winchester, 2005), but it may be difficult to generalise from the findings gained through such methods. Though not quite flexible as qualitative approaches, quantitative methods tend to allow generalisation of results and predictions (Winchester, 2005). Nevertheless, Bryman and Bell (2007) argued that mixed-method enquiry is like combining two different and separate paradigms of research methods. They argued that quantitative and qualitative procedures have their epistemological implications and should not be seen as complementary.

Climate change is a complex problem and the use of different approaches helped to bring to bear a better understanding of the different dimensions of the problem. Qualitative methods such as focus group discussions allowed the construction of meaning and incorporation of different perspectives regarding vulnerability and how households and communities respond to climate variability. Quantitative approaches such as crop drought vulnerability assessment and ecological surveys were useful in measuring the intensity of cases and extent of vulnerability.

3.5 Selection of study sites

Site selection is a vital component of the research design and this section describes how the study communities were selected. Major decisions about vulnerability and adaptation to climate change including decisions about agricultural production and consumption are taken at the household level and therefore it is necessary to conduct climate vulnerability assessments at the household scale (Thomas *et al.*, 2007). Nevertheless, households are connected to wider community that can greatly influence the decision-making process in relation to the use of productive resources of a particular household. Hence, the need to situate households level vulnerability and adaptation studies within the wider socioeconomic and cultural processes occurring at the village level (Thomas *et al.*, 2007). Further, major policy interventions to manage climate variability may be taken at the regional and national scales, hence the need to explore the interaction of climate and farming systems at these levels (Adger *et al.*, 2005). This thesis develops and applies innovative multi-scale approach by exploring vulnerability of food production systems to climate variability (particularly drought) in dryland farming systems at the national, district, village and household levels.

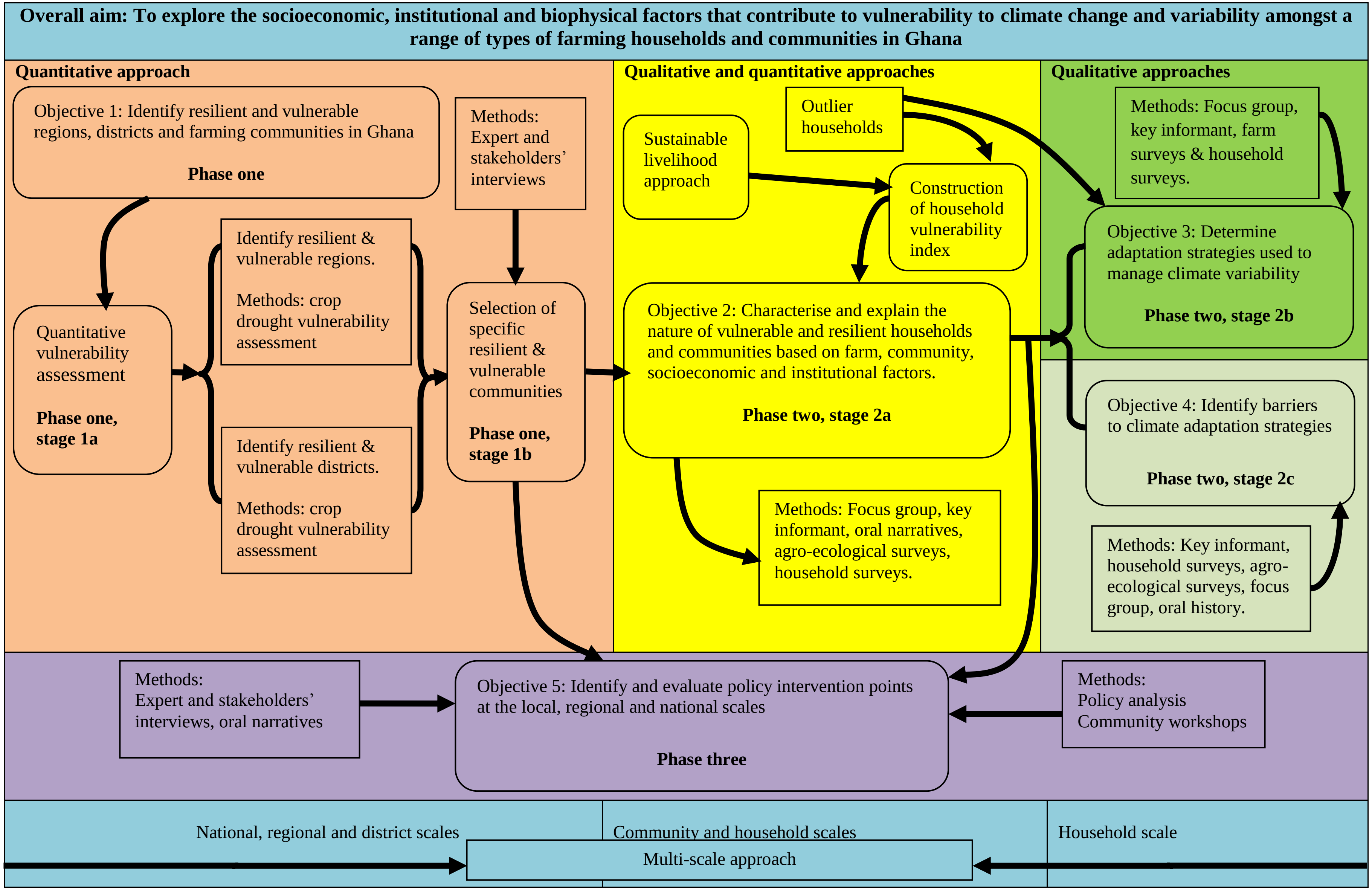

Figure 3.3: Research design and links between different methods and research objectives

As described earlier in the methodological flowchart of this thesis (Figure 3.3) the first aspect involved the identification of case study regions and sites to establish the relationship between agricultural productivity and climate change and variability. Hence, the selection of study sites started with a quantitative vulnerability assessment of crop production to drought to identify regions and districts in Ghana that were in the past "vulnerable" (defined as times when relatively minor perturbations in rainfall had large impacts on crop yields) and "resilient" (where even large rainfall perturbations had only minor impacts on crop yields) (Simelton *et al.*, 2009). This assessment highlighted the most resilient and vulnerable regions and districts in Ghana (see Chapter 4 for details on this).

The results of the quantitative vulnerability assessment highlighted the Ejura Sekyedumase district of Ashanti region and Bongo district of the Upper East region as the most resilient and most vulnerable districts respectively (Figure 3.4). These two regions (and districts) represent a range of different agro-ecological and socioeconomic factors. Within the resilient and vulnerable districts, 6 specific resilient and vulnerable farming communities (3 in each case) were selected for further research based on appropriate guidance from experts and stakeholders. During discussions and interviews, the experts and stakeholders provided valuable information that was used to select these farming communities. Three communities were selected from each district to allow comparisons to be made among communities within the same district without sacrificing the opportunity for in-depth qualitative analysis; hence, three was deemed a suitable number of communities.

The Ejura Sekyedumase district – the resilient district – (Figure 3.4) lies within the transitional ecological zone and experiences bi-modal rainfall patterns with the major rainfall season from March to July and the minor rainfall season from September to October (EPA, 2007) (see Table 3.1). Data from the Ghana Meteorological Agency show that the average annual rainfall in this district ranges from 1200–1500 mm with minimum and maximum temperatures of 20^{o}C and 32^{o}C respectively (EPA, 2003) (Table 3.1 and Figure 3.4). The transitional zone is characterised by potential evapo-transpiration of about 1430 mm per annum and relative humidity of 75% (EPA, 2003). The major crops grown include annual crops such as maize (*Zea mays*), groundnut (*Arachis hypogea*), yam (*Dioscorea spp.*), plantain (*Musa spp*.), cassava (*Manihot* *esculenta*) and rice (*Oryza sativa*). About 60% of the population in the district are involved in agriculture (GSS, 2000).

On the contrary, the Bongo district (i.e. vulnerable district) lies within the Sudan savannah ecological zone (Figure 3.4). The Bongo district, like many other districts in northern Ghana experiences a uni-modal rainfall pattern from May/June–Sept/Oct, which constitutes the main farming season (Dickson and Benneh, 1988). The average annual rainfall ranges from 800–1000 mm, with maximum temperatures of 35^{o}C and mean monthly minimum temperature of 21^{o}C maximum temperatures of 35^{o}C (EPA, 2003) (Table 3.1). The Sudan savannah zone is characterised by potential evapo-transpiration of 1652 mm per annum and relative humidity of 61% (EPA, 2003). Though, tree cover is low, the major trees of economic importance in the district include the baobab (*Adansonia digitata*), the dawadawa tree (*Parkia biglobosa*), shea tree (*Vitellaria paradoxa*), and the fig tree (*Ficus spp.*). The major crops grown in this district include sorghum (*Sorghum bicolar*), millet (*Pennisetum glaucum*), rice (*Oryza sativa*), groundnut (*Arachis hypogea*), guinea corn (*Sorghum vulgare*) and maize (*Zea mays*) (MoFA, 1997). The ethnic composition is mainly *Frafra*.

In terms of socioeconomic characteristics, the economy of the resilient district is based on commercial farming including crop production and livestock rearing, whilst that of the vulnerable district is mainly subsistence farming (GSS, 2000). Key differences between these two districts are highlighted in Table 3.2.

Table 3.2: Key characteristics of study districts

Characteristics	Ejura Sekyedumase	Bongo
Mean annual rainfall	1200–1500 mm	800–1100 mm
Rainfall patterns	Bi-modal	Uni-modal
Major rainfall	March–July	May/June–Sept/Oct
Minor rainfall	Sept–Oct	No data
Temperature	Min 20^{o}C, Max 32^{o}C	Min 20^{o}C, Max 35^{o}C
Agro-ecological zone	Transitional zone	Sudan savannah
Soil type (MoFA, 1998)	Luxisols, Nitrisols, Plinthosols and Cambisosls	Lixisols, Acrisols, Luvisols, and Gleysols
Population	81,115	77,885
% Population in agriculture	60%	90%

Source: EPA (2007) and data from Ghana Meteorological Agency, Accra

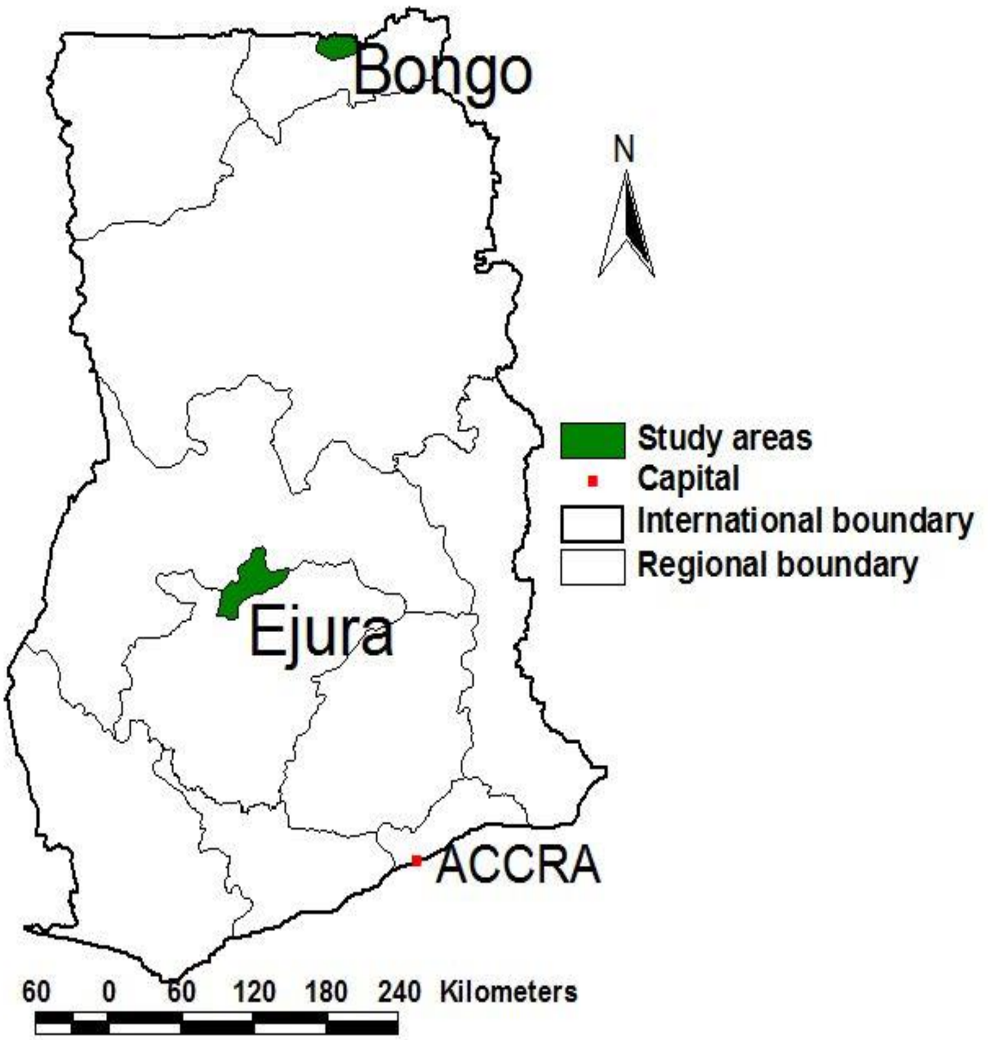

Figure 3.4: Ghana showing selected districts

3.6 Identifying resilient and vulnerable communities in Ghana

Having identified the resilient and vulnerable regions and districts, an exploratory study was undertaken to select specific resilient and vulnerable farming communities[5] by conducting expert and stakeholder interviews. Upon arrival in each study district, an initial meeting was held with the district director of the Ministry of Food and Agriculture (MoFA) and extension officers. During these meetings, the researcher and the purpose of the study were introduced to the staff. In all, 12 experts (including

[5] In this thesis, a farming community refers to a group of people living in a defined geographical area whose main occupation is agriculture.

agricultural extension officers) and 5 stakeholders' interviews[6] were conducted during the exploratory fieldwork.

Based on the literature, the following criteria were identified for the selection of specific farming communities; (i) the community should have been or is been exposed to some sort of climate anomaly (particularly drought); (ii) it should have characteristics that could be researched in line with the study's objectives; (iii) the farming community must be accessible by road; and (vi) the community must be willing to participate in the study during its entire period. With these criteria, several farming communities in both districts were eligible to be included in the research. Based on consultation with local experts and advice provided by agricultural extension officers, stakeholders such as NGOs, and local census data where this exists, three farming communities were selected from each district. These communities were selected because, according to the experts and stakeholders, they were exposed to some degree of climate anomaly (i.e. drought) and have either developed appropriate innovative strategies to deal with these (as in the case of communities in the Ejura Sekyedumase) or have not been able to deal with this climate anomaly (as in the case of the communities in the Bongo district). Based on the expert interviews Aframso, Babaso and Nyamebekyere (representing resilient communities), and Adaboya, Ayelbia and Vea (representing vulnerable communities) were selected (Figure 3.5).

These communities represented a range of agro-ecological zones, environmental and socioeconomic conditions that provided valuable context for in-depth analysis. These communities, therefore, constituted unique and manageable units, due to their small sizes, that allowed investigation into the complexity of vulnerability of farming systems and rural livelihoods to climate variability. The resilient communities are briefly described below.

a. **Aframso** – this community has been/is exposed to seasonal drought, and is a major cereal growing area, notably cultivating maize and rice. Despite the challenges posed by drought and occasional floods, the community has

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[6] Experts refer to professionals who have specialist knowledge in climate variability and how it affects crop production and rural livelihoods in agriculture-dependent households. Experts may not necessarily have any stake in how crop production is influenced by climate variability. Stakeholders refer primarily to persons that may have some level of understanding of these issues and have direct or indirect stake in the relationship.

developed innovative strategies to cope with the situation. According to MoFA experts, the innovativeness of this community has ensured that crop yields are not significantly affected by drought.

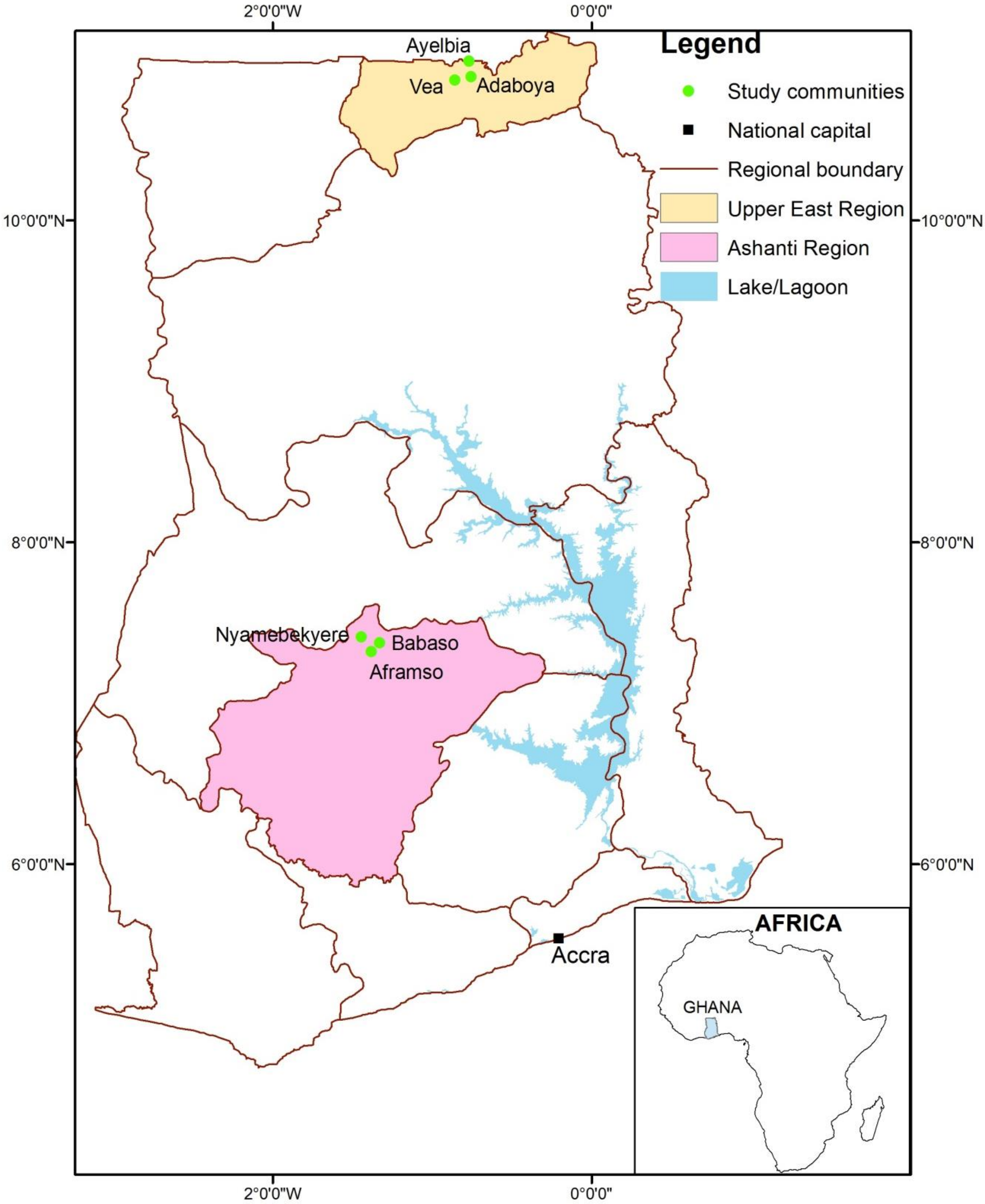

Figure 3.5: Ghana showing the study communities

b. **Babaso** – this community has experienced droughts of varying magnitude. According to the farmers, a major drought was experienced in 1983. However, extension officers and other stakeholders at Ejura Sekyedumase district suggested this community has developed various strategies to deal with this challenge. Babaso is located within the Ejura-Denteso soil association (including Haplic Lixisols and Gleyic Arenosol), which means the soils are susceptible to erosion (Sagoe *et al.*, 2006). The major crops grown in this community include maize, groundnut, yam, beans and plantain.

c. Nyamebekyere – this community has serious soil erosion problems linked to changes in the climate. Farmers in this community are also confronted with seasonal drought. Nyamebekyere is located on the main Ejura-Nkoranza road and about 35 km away from the district capital Ejura (Figure 3.5). It lies on longitude 1^{o} 25’W and latitude 7^{o}26’N. Soils at Nyamebekyere lie within the Damongo-Tanoso soil association (Ferric Lixisols and Dysteric Gleysols), which are formed over Voltaian sandstone (Sagoe *et al.*, 2006). Drought and the nature of the topography in this community make the soils dry and prone to erosion (Sagoe *et al.*, 2006). The major crops grown in this community include maize, groundnut, yam and rice.

The vulnerable communities that were selected are briefly described below.

a. **Adaboya** – this farming community which lies in the Sudan savannah agro-ecological zone has experienced persistent drought conditions which have affected crop yields quite significantly. This farming community depends entirely on rain-fed agriculture and the major crops grown include millet, sorghum, guinea corn and groundnut. There is no dry season farming because of a lack of irrigation facilities in this community.

b. **Ayelbia** – drought has been a persistent annual problem confronting households in this community. Crop yields have been significantly affected resulting in food deficits in most parts of the year. Some households in this community grow vegetables along the banks of the Red Volta which sometimes overflows its banks and causes serious flooding. Hence, this community is confronted with ‘double exposure’ to drought in the dry season and flood during the rainy season. According to farmers in this community, the flood in 2007 destroyed all their food crops and livestock, leading to serious famine. The main crops grown in this community include millet, sorghum, groundnut and rice.

c. **Vea –** this farming community was selected because it has been experiencing persistent drought. There is a large irrigation dam located in this community which allows some farmers to cultivate vegetables, especially tomatoes, during the dry season. Occasionally, this community experiences flooding due to the irrigation dam overflowing its banks and this could lead to destruction of crops and livestock. Major crops grown in this community include millet, sorghum and guinea corn. The presence of the irrigation dam allows some farmers to pursue fishing activities in addition to crop cultivation.

Table 3.3 highlights the key characteristics of the various farming communities.

3.7 Reconnaissance visits to selected farming communities

Having selected the specific farming communities, a reconnaissance visit was made to each in order to introduce the research. Entry into the community was made through the extension officers at the MoFA in each district. The researcher, together with the extension officers, made contact with the assembly member for each community by telephone in order to arrange a meeting to introduce the researcher and the research to the assembly member. After the initial meeting with the assembly member, the research team was introduced to the chief and those considered opinion leaders in each study community, and a date was set for a community gathering. In all, 6 community gatherings – one in each community – were held where the research aim and the nature of the research were explained to attendees and the researcher indicated that participation in the study was voluntary. During such gatherings, opportunity was given for members of the community to ask questions relating to the research. As part of the reconnaissance visits, transect walks (e.g. Pretty, 1995; Sallu *et al.*, 2009) were undertaken with opinion leaders in each of the six communities to obtain an overview of the topography, soil, land use and other environmental conditions prevailing in each community (see Section 3.10.3 for details on transect walks). These transect walks helped to refine the research objectives and questions.

Table 3.3: Key characteristics of the study communities

Characteristics	Resilient communities			Vulnerable communities		
	Aframso	**Babaso**	**Nyamebekyere**	**Adaboya**	**Ayelbia**	**Vea**
Climate anomaly	Drought	Drought	Drought	Drought	Drought, floods	Drought
Agro-ecological zone[7]	Transitional zone	Transitional zone	Transitional zone	Sudan savannah	Sudan savannah	Sudan savannah
Farming seasons	Two: major and minor seasons	Two: major and minor seasons	Two: major and minor seasons	One main season (May – Sept)	One main season (May – Sept)	One main season (May – Sept)
Major crops[8]	Maize, yam, rice, cassava & plantain	Maize, beans, cassava, yam & groundnut	Maize, beans, cassava, yam & groundnut	Millet, sorghum, groundnut & guinea corn	Millet, sorghum, groundnut & guinea corn	Millet, sorghum, groundnut & guinea corn
Type of farming	Bush farming	Bush farming	Bush farming	Compound farming[9]	Compound farming	Compound farming
Soil type	Ejura series of soils	Haplic Lixisols and Gleyic Arenosol	Ferric Lixisols and Dysteric Gleysols	Bongo series of soils	Bongo series of soils	Bongo series of soils
Type of tenure system[10]	Matrilineal	Matrilineal	Matrilineal	Patrilineal	Patrilineal	Patrilineal
Livelihood options	Crop production and animal production	Crop production and animal production	Crop production, charcoal production, animal production	Entirely crop farming with few livestock farmers	Entirely crop farming with few livestock keepers	Crop farming with few engaged in vegetable production
Ethnic composition	Majority *Akans*	Majority *Akans*	Majority *Akans*	Majority *Frafra*	Majority *Frafra*	Majority *Frafra*

[7] Data from Ghana Meteorological Agency, GMet
[8] Data from MoFA (2007)
[9] Compound farming is the cultivation of land around the close vicinity of the homestead. This is a common practice in the vulnerable communities.
[10] See Yaro (2010); MLF (1999)

3.8 Training of research assistants and pre-testing of questionnaire

Climate change is a complex problem which is not helped by the different terms used to describe it in different parts of Ghana. Hence, it was necessary to run a training programme for research assistants who were recruited to help with data collection. Four research assistants and one interpreter were recruited based on their technical competencies including their communication and writing skills, as well as their ability to act objectively within interview situations. The research assistants were thoroughly briefed by the principal investigator on the nature and significance of the study. These assistants were indigenes of the study area and spoke the local dialects of the farmers. Two of the research assistants were graduates in agricultural science and the remaining two were extension officers with diplomas. The researcher did not understand the local dialects in the vulnerable communities and therefore recruited a graduate level research interpreter who spoke the *Frafra* and *Gruni* languages. The research interpreter holds a degree in agricultural science and a native speaker of *Frafra* and *Gruni*, which are the main languages of the vulnerable communities. Two days were used in training the research assistants to ensure that all interviewers asked questions in similar fashion to reduce any ambiguity.

The questionnaire for the household survey (Appendix 1) and the question guide for the focus group discussions (FGDs) (Appendix 2) were pre-tested in the second week of July, 2010 at Ejura. Eight randomly selected households participated in the pilot testing in order to gauge the kind of responses that could be anticipated in the field. Two FGDs were also held to reflect on the applicability of using focus groups for a study of this nature. After the pilot of the household survey, the questionnaire was modified by deleting irrelevant and ambiguous questions. For example, it was realised that farmers found it difficult to use a ‘mental model of climate’ to link climate variability and livelihood activities. Thus, questions relating to mental models were deleted from the final questionnaire for the main fieldwork. During the main fieldwork, the research team met at the close of work every day to discuss the day’s work and deliberate on any issues arising.

3.9 Sampling methods

Different sampling methods were employed for this study depending on the type and source of data needed. The selection of the resilient and vulnerable regions was based on the analysis of rainfall and yield data. Expert and stakeholder interviews were used to select specific resilient and vulnerable farming communities within the resilient and vulnerable regions during the exploratory fieldwork. Household questionnaire surveys were based on a stratified random sample where households were stratified according to wealth and a random selection made from this (see Saunders *et al.*, 2009; Bryman and Bell, 2007). Forty-five households were randomly selected and interviewed in each of the 6 selected farming communities, giving a total sample of 270 households. Purposive sampling was used to identify key informants (Bryman and Bell, 2007), while experts and stakeholders were selected using a combination of purposive and snowball sampling. This is because some respondents from these groups were identified during the exploratory study and more were identified during the FGDs.

3.10 Research methods

Empirical data used in this thesis is based on three rounds of fieldwork; an exploratory study from February–March, 2010, main fieldwork in June–September, 2010 and supplementary fieldwork in June–August, 2011. Table 3.4 shows which research methods were used to achieve the research objectives. The strengths and limitations of these research methods are flagged up later in this chapter in Table 3.5.

Table 3.4: How research tools or methods are related to the research objectives

	Research objectives				
Research tool or method	Identify resilient & vulnerable regions	Characterise households & communities	Identify adaptation strategies	Identify barriers to adaptation	Identify policy options
Focus group		X	X	X	
Key informant		X	X	X	
Transect walk		X			
Ecological survey		X	X	X	
Seasonal calendars		X	X	X	
Questionnaire survey		X	X	X	
Expert interviews	X				X
Policy analysis				X	X
Oral history		X	X	X	

X indicates that the particular method was used to collect data to achieve specific objective.

3.10.1 Relevance of participatory methods to this research

Participatory methods are research methods that allow local people the opportunity to participate by sharing their experiences and knowledge in an effort to find solutions to local issues (Chambers, 1997). Participatory methods involve sharing knowledge and expertise between scientists and non-scientists (local people) in a collaborative manner (Ballard and Belsky, 2010). In this regard, researchers act as facilitators and learners and seek to assist local people in the choice and use of appropriate participatory methods (Chambers, 1994). This allowed local communities to own the information generated.

Participatory methods have certain advantages that can be derived if well executed. First, the active involvement of local people or social actors in the research process can stimulate social action or change (Ziervogel and Calder, 2003). Second, by using participatory methods such as FGDs, marginalised and underprivileged communities or groups may be empowered, helping to build local capacity to manage problems such as climate variability (Kothari, 2001). This has the potential to increase their self-belief and confidence in their own capabilities (Chambers, 1994).

Despite their usefulness, the use of participatory methods in this thesis was not without limitations. For example, the involvement of local people in this thesis was time consuming and expensive. To overcome this challenge, discussions at focus groups and household surveys were moderated by the researcher to ensure that discussions were relevant to the scope of the research and digressions by participants were kept to the minimum. Serious methodological concerns have been raised in relation to the extent to which findings generated from context–specific participatory approaches such as focus group discussions and transect walks can be generalised (Martin and Sherington, 1997). To address such shortcomings, participatory approaches were complemented by quantitative approaches such as crop drought vulnerability assessment and time series analysis that allowed the intensity of cases and extent of vulnerability to be measured, thereby providing scope for generalisation.

Moreover, participatory approaches as a way of enhancing the outcomes of research has been challenged as the views and perspectives of minority and the less ‘powerful’ are not reflected in such studies (see Cooke and Kothari, 2001). In many of the farming communities, the more powerful members of the community tried to hijack discussions at focus groups. In this regard, efforts were made by the researcher to encourage all participants to share their experiences during focus group discussions. Farmers who appeared intimidated by the presence of certain individuals were later approached for one-to-one discussions. Such one-to-one discussions with the less powerful members of the communities provided valuable insights into the power relations at work at the local scale.

Participatory methods were used in this research because they allowed the researcher to gain local insights into the complexity of climate variability and how it affects food production systems and rural livelihoods in the study communities. For instance, using participatory methods provided valuable insights into how livelihood activities of households in the study communities have been adversely affected by climate variability. Households have used indigenous knowledge to construct local climate models and develop innovative strategies to cope with climate variability. It is therefore necessary that this knowledge is recorded and synthesised so as to explore the nature and extent of vulnerability and coping measures used by these farmers. This provides time-tested and robust coping and adaptation strategies that can be used to reduce the impacts of climate change and variability on the livelihoods of rural, agriculture-dependent communities. Several writers have used participatory methods including FGDs and climate timelines in climate change studies (see Roncoli, 2006; Mertz *et al.*, 2009; Tschakert and Sagoe, 2009; Van Aalst *et al.*, 2008).

3.10.2 Focus group discussions

Focus group discussions (FGDs) informed by Hopkins (2007) were conducted in each of the 6 communities. FGDs involve a "small group of people discussing a topic or issues [research problem] defined by a researcher" (Cameron, 2005, p. 116). In FGDs, the researcher plays the role of a moderator or facilitator to structure the discussion (Saunders *et al.*, 2009). FGDs bring about group interaction, which may be lacking in a one-to-one interview (Darlington and Scott, 2003) and allow different meanings that the local farmers may have about climate change and variability to be fully explored (Bryman and Bell, 2007). One major weakness with FGDs, however, is that group dynamics might create problems for certain participants. For instance, certain individuals within the group may feel shy to express their opinions in the presence of certain personalities (Darlington and Scott, 2003). The purpose of the FGDs was to gain local insights on climate change and how it is perceived to affect livelihoods in the communities. Information was also solicited on how the community copes with the changes in the climate.

Based on recommendations in the literature regarding group sizes, 5–12 farmers were selected for the FGDs in each community (see Kitchin and Tate, 2000; Hopkins, 2007). To ensure good representation of farmers with different socio-cultural backgrounds, careful consideration was given to gender, age and wealth groups in the selection of participants (see Hopkins, 2007). Participants were selected based on their considerable farming acknowledge and environmental change in the communities during the household questionnaire survey. Using FGDs (Figure 3.6) in this research provided useful local insights that could not be obtained from household questionnaire survey or ecological approaches. The main topics that were discussed included the livelihood capital assets in the communities, coping and adaptation strategies, and the temporal scale and rate of evolution of changes that have taken place in the communities since the 1960s (the reasons for this period is explained later in Chapter 4). The researcher moderated the discussions and asked probing questions where further clarifications were needed (see Appendix 2 for question guideline for FGDs). In all, 9 FGDs were conducted with farmers in the 6 communities – one in each community. However, during FGDs in the vulnerable communities, it was discovered that social and cultural factors constrained women from expressing themselves in the presence of male farmers. This was more so when women had answers that conflicted with answers already provided by their husbands. In this case, the benefits of participatory approaches as a way of enhancing the outcomes of research through the representation of people with different socioeconomic background were not derived as the views and perspectives of minority and the less ‘powerful’ were not reflected. To improve participation of women in the vulnerable communities, separate FGDs were thus held with female farmers and women groups on three occasions (Figure 3.7). This enabled an understanding of power relations within the study communities and how this affects households’ vulnerability to climate variability (particularly drought).

Figure 3.6: Focus group discussion with community members, Aframso, July, 2010

Figure 3.7: Focus group discussion with female farmers, Vea, August, 2010

During the FGDs, seasonal calendars and climate timelines (Roncoli, 2006) were constructed with the community. Indeed, it has been argued that climate timelines allow researchers to explore communities' recollections of past climatic (rainfall and temperature) patterns and how these have influenced crop production (Ziervogel and Calder, 2003; Van Aalst *et al.*, 2008). Information from seasonal calendars and climate timelines constructed with farmers are used in Chapters 6 and 7 to determine adaptation pathways and identify barriers to climate adaptation.

Additionally, the community members present at the FGD were asked to list the various resources that are important to their livelihoods. These resources were categorised into the five capital assets (natural, physical, social, financial and human assets) based on the sustainable livelihood framework (Scoones, 1998). Information was obtained on how these assets are affected by changes in the climate and how the community copes with such changes. Social capital was assessed by identifying the kind of family systems and social networks in these farming communities. Other social capital types that were assessed include community-based and agricultural-based associations and NGOs which may provide support to their members in times of need. All FGDs were audio recorded in the farmers' local dialect which was translated into English using linguistic experts. Generally, each FGD lasted between one to two-and-a-half hours.

3.10.3 Transect walks

FGDs were complemented by transect walks with community members. A transect walk is a participatory approach whereby the research team walks through a village or community (Sallu *et al.*, 2009; Pretty, 1995). The research team was accompanied by members of the local community to facilitate interactions between the community and the research team. Each transect walk team consisted of the researcher, the research assistants, the chief (or his/her representative), the assembly member, and other opinion leaders such as the chief farmer. At least one transect walk was conducted in each of the 6 selected farming communities during the reconnaissance study to get an overview of the significant social and physical features including the kind of agro-ecosystem (i.e. topography, soil type, vegetation). Where possible, a second transect walk was conducted after the FGD, during which members of the community illustrated with examples the issues that had been highlighted during the discussions.

3.10.4 Wealth ranking

A wealth ranking exercise was conducted in all 6 farming communities. Wealth ranking has been used to ensure sufficient representation of the different wealth groups in the communities (Sallu *et al.*, 2009; Rennie and Singh, 1996). Wealth ranking may be considered to be invasive by the farmers and impractical when you have many households within a community (Rennie and Singh, 1996). This problem was overcome by adapting the procedure followed by Reed (2005) in categorising wealth of pastoralists in the Kalahari, Botswana. Hence, the indicators for wealth ranking were developed based on the perceptions of wealth and poverty of the local community and individual households evaluated at the time of the interview (Reed, 2005). Where there was an under-representation of any wealth group, key informants were used to identify appropriate households to supplement the sample.

For vulnerable communities, a household was considered rich if they had at least 3 of 6 local indicators of wealth (i.e. (1) 15 or more cattle; (2) harvest 20 bags of millet/sorghum; (3) harvest 10 bags of groundnuts; (4) own a pair of bullock for farming activities; (5) live in a zinc or wood roofed house; and (6) feed the family all year round with surplus). A poor household would be expected not to have more than one of these indicators. In the resilient communities, a rich household was classified as those that have at least 4 of possible 7 local indicators of wealth (i.e. (1) ability to pay children's school fees; (2) live in aluminium roofed building; (3) harvest 50 bags of maize; (4) harvest 20 bags of beans or groundnuts; (5) have more than 20 cattle; (6) have more than 30 sheep/goats; and (7) have a motor bike). A poor household in the resilient community was not expected to have more than two of these 7 local indicators of wealth.

3.10.5 Household questionnaire survey

A structured questionnaire was used to solicit information from farmers at the household level to assess livelihood options at the household and community scales. This study adopts the most common definition of household used in Ghana "as constituting of a group of people who own the same productive resources, live together and feed from the same pot" (Yaro, 2006, p. 129). In this regard, the household usually is deemed to comprise a married couple and their children. To characterise households and farming communities, this thesis followed the framework proposed by Fraser (2007) who suggests that vulnerability to climate change in food systems can be assessed by looking at the household (agro-ecosystem), community (livelihoods) and institutions (at the local, regional and central government). This framework was slightly modified to take into account local aspects such as socioeconomic factors that can potentially influence food production systems' vulnerability to climate variability especially in developing countries. At the household level, participatory methods were used to determine locally-relevant indicators of agro-ecosystem resilience (the ecological survey is described in detail later in this chapter).

At the community level, this study used the sustainable livelihood approach (Scoones, 1998), where capital assets (financial, human, natural, physical, and social) were assessed during a household questionnaire survey (see Appendix 1). Households were also asked to indicate some of the factors that make them more or less vulnerable to climate variability. This information was used to construct the household livelihood vulnerability index (see Chapter 5 for details). The type of farming and the kinds of crops as well as land tenure issues were assessed. Information on family types, gender issues, cultural values, and traditional knowledge of the community which may affect their capacity to adapt to climate change and variability were collected and evaluated. In Ghana, traditional knowledge has, to a large extent, been used by farmers to solve varied issues including climate change related problems (e.g. Gyampoh *et al.*, 2009).

An assessment was undertaken to determine the effectiveness of institutional arrangements at the local, regional, and national levels. Data on governmental assistance in the form of subsidies and the type and roles of the various institutions involved in agricultural development and environmental protection in Ghana were collected. Information on the role of NGOs, community-based organizations and faith-based organizations was also collected and evaluated. This is necessary because these organizations are often used as proxy indicators for the presence of good governance (e.g. Brouwers, 2011).

The household questionnaire survey also assessed the adaptation and coping responses used by the farmers in the study communities. Data were collected on new crop varieties, water resource management technologies, information systems for weather forecasting etc. Data were also collected on the availability of, and accessibility to, government subsidies, insurance, and general government policies and programmes particularly on land tenure systems and land use. Further, data were collected on type of farming, irrigation practices, tillage practices, moisture conservation techniques, timing of farm operations as well as sources of credit for farm operations etc. (again, see Appendix 1). Information collected on coping and adaptation strategies formed the basis of Chapter 6.

Information was also collected on barriers to climate adaptation strategies including access to information on early warning systems for farmers, financial constraints, availability of, and accessibility to, extension advice, illiteracy and how it affects accessibility to information, technological constraints etc. Traditional belief systems and norms which may also serve as barriers to the adaptation strategies were identified and evaluated. This information provided insights into the difficulties confronting farmers in their attempts to implement appropriate strategies to cope with and adapt to climate variability and change. This information formed the basis of Chapter 7. The household survey was also used to elicit the perception of farmers regarding rainfall and temperature patterns in the study regions.

In all, 270 household surveys were conducted in the 6 study communities (45 questionnaires in each). Although random sampling was used, factors such as age, gender, and wealth group of the farmers were considered in order to have a representative of the various social groups within each community. The questionnaire consisted of both closed and open-ended questions (Appendix 1). It was conducted in the respondents' homes and this allowed the research team to make a preliminary assessment of their socioeconomic conditions (Orlove *et al.*, 2010). All interviews were conducted in vernacular, with research assistants acting as interpreters where appropriate, and were voice recorded with the consent of the respondents. The recorded interviews were later transcribed with the assistance of linguistic expert. The length of surveys was unrestricted but generally lasted between forty-five minutes to one-and-half hours. Questions referring to climate change were deliberately deferred to the end of the questionnaire surveys to avoid biases and prejudice in answers.

3.10.6 Key informant interviews

During the FGDs and household questionnaire survey, individuals who demonstrated appreciable knowledge on environmental change and agricultural production were selected for key informant interviews. Interviews with key informants were accompanied by visits to points of interest, where appropriate (Figure 3.8). Opinion leaders such as chiefs, queen mothers, and assembly members were also interviewed. The key informant interviews allowed in-depth discussion and validation of the main issues that were highlighted in the household questionnaire survey and FGDs. Key informant interviews took place on a one-to-one basis to ensure confidentality of responses, and lasted between forty minutes and one-and-a-half hours.

Figure 3.8: Key informant explaining a point to researcher at a point of interest, Nyamebekyere, July, 2011

3.10.7 Oral histories

An oral history is a critical method used by people to reflect upon specific events and practices in the past (Bryman and Bell, 2007). The use of oral history as a research method has gained prominence in geographical and climate research (Powell, 2008). Results from the output of research objective 2 (characterising households and communities) suggested that there were certain ‘outlier households’ in both the resilient and vulnerable communities. For instance, construction of a household livelihood vulnerability index (see Chapter 5) highlighted that there are certain households that were extremely vulnerable in the so-called resilient communities. The opposite occurrences were observed in the vulnerable communities, where there were certain households that were quite resilient. Oral narratives were conducted with outlier households to provide insights into the past events that have shaped the livelihood opportunities of such households. Oral narratives from outlier households were compared and contrasted with those from typical households within these communities to highlight indicators or factors that might influence vulnerability of households to climate variability.

3.10.8 Expert interviews and policy analysis

A study on food production systems' vulnerability to climate change and variability cannot be complete without an analysis of the policy context. Results from the different types of vulnerable community (*the output from objective 2*), the adaptation strategies pursued (*the output from objective 3*) and an understanding of the barriers to reducing vulnerability (*the output from objective 4*) were presented to experts and policy makers in a series of expert interviews in order to elicit possible policy implications of this work. Experts who participated in the study included the United Nations Framework Convention on Climate Change (UNFCCC) national focal point and the United Nations Convention to Combat Drought (UNCCD) national focal point, all based at the EPA, Ghana. Other experts were from the national universities, governmental agencies and ministries, NGOs, regional and district directors of food and agriculture, and extension officers. These experts were purposefully selected. However, further experts were involved through snowball sampling techniques (Bryman and Bell, 2007). In addition, specific policies were analysed to determine the effectiveness of these policies in terms of food security. These include the Food and Agriculture Sector Development Policy, National Climate Change Policy Framework, National Action Plan to combat desertification, National Land Policy and National Climate Change Adaptation Strategy. These policies were selected in consultation with experts in Ghana and analysed through the use of content analysis (Krippendorff, 2004). These policies were read by the researcher to highlight key points before having interviews with the experts.

3.10.9 Agro-ecological surveys

Agro-ecological methods can be integrated with participatory methods to provide useful insights into the drivers of vulnerability to climate variability at the household and community levels (Roncoli, 2006). Agro-ecological surveys were conducted to triangulate the issues that were highlighted in the household surveys, FGDs and key informant interviews. During the household survey, farmers were asked to provide information on the geographical location of their farms. After the household surveys, two households were randomly selected from all geographical locations of the households that participated in the survey and their farms visited for the agro-ecological survey. Households were stratified according to geographical location of the farm and wealth group, and a random sample selected from these households during FGDs. The researcher and research assistants, together with a field taxonomist, visited these two farms in each community.

During the agro-ecological survey, the research team classified the natural ecosystem and agro-ecosystem's health (either fragile or robust) by looking for evidence of issues such as soil degradation, soil health, presence of gullies and rills, type of soils and soil depth, and levels of organic matter (Stocking and Murnaghan, 2001). Indicators of agro-ecosystem resilience such as diversity of crops and plant species were also evaluated. Diversity was measured in terms of species diversity and species richness (Gliessman, 2007). Within each agro-ecosystem and natural ecosystem, two 25 m × 25 m quadrats (plots) were randomly demarcated with flagged pegs in a similar manner as followed by Addo-Fordjour *et al.* (2008). Within each quadrat, all woody plant species including trees, shrubs and lianas as well as crop species were identified and counted. This was replicated twice in each agro-ecosystem and natural ecosystem within the selected farms. In all, there were 4 quadrats in each selected farm, making a total of 8 quadrats in each community. Identification of different plant species was conducted with the assistance of a trained field taxonomist and with reference to appropriate local flora and manuals on plant species (e.g. Poorter *et al.*, 2004).
Table 3.5 presents the strengths and limitations of the main research methods that were used to collect data for this thesis.

Table 3.5: Strengths and limitations of the research methods

Method	Strengths	Limitations	Practical solutions
FGDs	Helped to validate secondary information. Issues on vulnerability that are deemed significant were brought to the fore.	Shyness created problems and certain individuals dominated. People who had problems with others did not want to participate in the discussions.	Researcher moderated to make sure each participant was given opportunity to express themselves (e.g. Hopkins, 2007). Gender based FGDs were held.
Ecological survey	Helped in triangulating information from other methods such as FGDs.	Difficulties in selecting specific farms and the indicators of vulnerability and agro-diversity.	Only woody plant species including trees, shrubs and lianas and crop species were counted. Type and depth of soil were documented (Stocking and Murnaghan, 2001).
Key informant interviews	Allowed in-depth discussions on main issues highlighted in FGDs.	Difficulties encountered in identifying appropriate key informants.	Relied on opinion leaders such as chiefs, assemblyman and chief farmers. More informants identified during the FGDs.
Questionnaire survey	Allowed exchange of knowledge between researcher and participants. Relatively cheaper, flexible and adaptable.	May be time consuming.	Researcher kept respondents on the topic under discussions and avoided unnecessarily digressions that did not add to the interview responses.
Expert and stakeholders interviews	Provided expert opinion on vulnerability of farmers in the study area.	Difficulty in getting experts to participate in interviews.	Used personal contacts in the various ministries to link up with experts. Booked interview appointment to suit experts and stakeholders.
Seasonal calendar	Understanding the relationships between natural resources-based livelihoods, climate and disasters.	Complex and time consuming Memory lapses made this difficult for farmers. Very little time for discussions.	Concentrated on only droughts and floods, where necessary. Prompted participants with significant local and national historical events.
Oral history	Very informative and highlighted past experience and events. Allowed the understanding of livelihoods problems	Memory lapses and distortions caused potential biases in responses by farmers.	Cross-checked narratives with household questionnaire surveys that were collected before the oral history. Respondents were also prompted with significant local and national historical events.
Policy and institutional analysis	Allowed the targeting of specific policies to enhance the relevance of research.	Difficulty in getting access to policy documents from governmental agencies and institutions.	Used personal contacts in the ministries to get access to policy documents. Also, during expert interviews, request was made for policy documents and other secondary data.
Transect walk	Understanding biophysical resource vulnerability and livelihoods problems Very interactive and informative for researcher.	Many issues were addressed within a short time thus limited learning outcomes on any particular subject.	Concentrated on significant social and physical features of the community. Recorded and photographed features for later discussions with key informants.

Source: Developed from Warrick (2009)

3.11 Data capture and analysis

3.11.1 Data capture

Data were captured in the field by using appropriate tools such as a field note book, digital recorder, and digital camera. The questionnaire for household surveys had spaces where respondents were asked to provide their responses. Some of the questions on the questionnaires required the respondents to just tick the appropriate responses that may be applied to them. For oral narratives, FGDs, expert interviews and transect walks, a digital recorder and camera were used to capture responses. Electronic data captured in the field were stored on password protected computers.

3.11.2 Qualitative data analysis

Qualitative data were collected through a mixture of household questionnaire survey, key informant interviews, expert interviews and FGDs. Oral narratives and FGDs were recorded in the native language and later translated by linguistic experts. Digital recordings of FGDs and oral narratives from each community were listened to repeatedly to ensure accuracy. Qualitative data were coded and indexed through intensive content analysis and the major themes that emerged analysed (Saunders *et al.*, 2009; Krippendorff, 2004). These major themes were triangulated through a more in-depth agro-ecological survey and any contradictions were clarified through key informant interviews (Sallu *et al.*, 2010; Reed, 2005). Structuring qualitative data into various themes allowed the categorisation of the responses and identification of those that diverged from the common themes. Appropriate quotes from farmers and experts were used to provide more emphasis to enrich the discussions.

3.11.3 Quantitative data analysis

Quantitative data were coded in a way that MS Excel (Version 2007) and Predictive Analytic Software (formerly Scientific Package for Social Sciences –SPSS) understand to enable appropriate statistical analysis to be made. Data were analysed in Predictive Analytic Software using descriptive statistics and compared means (Kinnear and Gray, 2012). Data were presented in the form of graphs and tables to give graphical representation to the data.

To establish the extent of climatic variability in the study communities (see Section 4.4, Chapter 4), a time series analysis was conducted for rainfall and temperature data obtained from the Ghana Meteorological Agency covering a period of 1961–2007, when data were available. The time series analysis was done using Microsoft Excel (Version 2007). This time series analysis was also used to substantiate claims made through oral history as well as climate timelines that were constructed during focus group discussions with farmers. In addition, time series analysis was used to calculate linear trends of yields to determine the sensitivity of crop yield to rainfall perturbations (see Chapter 4, Section 4.2 for details).

A one-way Analysis of Variance (ANOVA) was also performed where appropriate (i.e. where data were parametric) to test for statistical differences between and among data collected from resilient and vulnerable households and communities (Kinnear and Gray, 2012). The ANOVA was conducted following the procedure in Kinnear and Gray (2012). For the ANOVA, the dependent variables were the coping and adaptation strategies identified in the study communities. The independent variables included socioeconomic factors such as age, gender, education, wealth groups, household size, land tenure system, farm holding as well as agro-ecological setting that could potentially influence the household vulnerability to climate variability and change. Where significant differences existed, the least significant difference (LSD) and Duncan post-hoc tests were used to separate the means of the various communities (Kinnear and Gray, 2012). All analyses were conducted at a significance level of 5%.

K-means clustering using Statistica 7 software was used to cluster the vulnerability of different regions and districts as well as the communities and households within the study area (see Chapters 4 and 5). K-means cluster analysis seeks to group cases into distinct clusters by seeking groups that minimise variability within clusters and maximise variability between clusters (Levin and Page, 2000). K-means clustering has been applied to several geographical problems (e.g. Levia and Page, 2000; Ahern *et al.*, 2007) and its utility for spatial vulnerability assessments in dynamic farming systems is explored in this thesis.

3.11.4 Analysis of agro-ecological data

For ecological data, the Shannon-Wiener Index of diversity was used to quantify the diversity of the plant and crop species within both the agro-ecosystems and the natural ecosystems. For ecological data, the Shannon-Wiener combines both species richness and abundance, and is the most commonly used index in ecological studies (Gliessman, 2007). The Shannon-Wiener Index of diversity is given by:

$$H= -\Sigma[(n^i/N)\times \ln(n^i/N)]$$

Where n^i = number of individuals or amount of each species (the *ith* species) and N = total number of individuals for the site, and ln = the natural log of the number.

3.11.5 Policy analysis

Content analysis of the key policy documents (Krippendorff, 2004) that relate to climate adaptations and food security in Ghana was undertaken (including analysis of the Initial National Communication (INC) to the UNFCCC, the National Action Plan to combat drought and desertification (NAP), and Food and Agriculture Sector Policy (FASDEP)) to highlight the key themes covered by such policies. These policy documents were carefully read to fully understand the contents and the main message covered by these policies. Also, a discourse analysis of each policy document was undertaken by examining the dominant narratives covered in each policy document (e.g. Stringer *et al.*, 2009). The main themes that emerged from the content analysis of a particular policy document were then checked against other policies to highlight any similarities or contradictions of various policies that were meant to address similar concerns, in this case climate variability and food security.

3.12 Positionality and ethical considerations

The positionality of the researcher is extremely important in conducting this kind of research (Rose, 1997; Twyman *et al.*, 1999). To address this, considerable thought was given to the appearance, dress code, and the way that the researcher and research assistants approached participants. This was particularly important in the vulnerable communities located in northern Ghana, considering the fact that the researcher comes from southern Ghana. In this regard, attempts were made to clearly articulate the nature of the research during the household surveys and FGDs. The research team was thoroughly briefed on the importance of positionality in research of this nature. Hence, the research team related to research participants in a manner that did not create any suspicion (Twyman *et al.*, 1999). Where women were interviewed, this was mostly done in their house in the presence of other members of the households. During FGDs with female farmers, sitting arrangements were carefully orchestrated to ensure that the women were comfortable and all such meetings were held in open areas such as the community centre. Careful consideration was given to ethnic balance by liaising with tribal chiefs to encourage their people to participate in the study. In rural communities in Ghana, tribal chiefs are quite influential and well respected in their communities.

Ethical considerations are crucial for studies that involve human participants because of the need to safeguard the research participants, the research process and the credibility of research results (Flick, 2009). Ethical dilemmas focussed on confidentiality and participants' consent. In terms of confidentiality, electronic data were stored on encrypted memory sticks and password protected computers and uploaded to the University of Leeds N/M drives via remote access, where possible. Participants were assured that any direct quotes that are used would be anonymised. All participants in the interviews were asked to sign a participant consent form. This was after they had been given information sheets that sufficiently explained the purpose and the nature of the research. Verbal consent was obtained from participants who could not sign their names or read the information sheets (in which cases, the sheets were read out to them). Participants were made aware that their involvement in the research was voluntary, that they would not be compensated and that their names would not be revealed. Participants were given the opportunity to ask questions that might be bothering them before signing the consent form. Participants were also assured that they could withdraw from the research at any time. The research protocol that guided this study was approved by the University of Leeds Ethics Review Committee (Approval Ref. No. AREA 09-030).

3.13 Conclusions

This chapter has described how the study communities that participated in this research were selected. The research design as well as the use of participatory methods in this study has been justified. This chapter contributes to wider academic debate in relation to how different methods (i.e. quantitative and qualitative approaches) at different scales can be integrated to assess vulnerability of dryland farming systems. Climate change is a complex problem interacting with different processes at different scales (Cash and Moser, 2000). The use of a mixed-method approach allowed validation and deepening of understanding of the main issues involved in vulnerability of farming systems and livelihoods to climate variability through triangulation, thus providing a significantly richer understanding of the different dimensions of the problem through its exploration across scales. Combining different methods with valuable insights from local farmers provided local insights that enhanced learning by the researcher and members of the study communities. Having described how the various data were collected and analysed, the next chapters (Chapters 4–7) present the findings from this study.

CHAPTER 4

MAPPING THE VULNERABILITY OF CROP PRODUCTION TO DROUGHT IN GHANA[11]

Summary

This chapter outlines the results and data collected in identifying vulnerable and resilient farming regions, districts and communities in Ghana (objective 1). It applies and evaluates new multi-scale, multi-indicator methods for assessing the vulnerability of crop production to drought at a national and regional scale. It does this by identifying differences across and within ten regions of Ghana, a country that faces many climate and crop production challenges typical of sub-Saharan Africa. In particular, this chapter illustrates how a quantitative national and regional assessment is a critical first step in identifying differences in the drought sensitivity of food production systems. It shows how such an assessment enables the formulation of more targeted district and community level research that can explore the drivers of vulnerability and change on a local scale. Finally, the chapter proposes methodological steps that can improve drought sensitivity and vulnerability assessments in dynamic dryland farming systems where there are multiple drivers of change and thresholds of risk that vary in both space and time. Results show that the vulnerability of crop production to drought in Ghana has discernible geographical and socioeconomic patterns, with the Northern, Upper West and Upper East regions being most vulnerable. Partly, this is because these regions have the lowest adaptive capacity due to low socioeconomic development and have economies based on rain-fed agriculture. Within these regions there are considerable differences between districts that can be explained only partly by socioeconomic variables with further community and household-scale research (see Chapter 5) required to explain the causes of differences in vulnerability. The chapter contributes to the scientific literature on vulnerability assessment by highlighting that national and regional scale multi-indicator

[11] This chapter is developed from the published journal article of Antwi-Agyei, P., Fraser, E.D.G., Dougill, A.J., Stringer, L.C., and Simelton, E. (2012) Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography*, 32(2): 324-334.

vulnerability assessments are a vital (and often ignored) first step in assessing vulnerability across large areas.

4.1 Introduction

Major decisions about vulnerability and adaptation to climate change are taken at the household level (Thomas *et al.*, 2007). However, such decisions are also taken in the context of wider socioeconomic and cultural processes occurring at the village, national and regional levels (Thomas *et al.*, 2007). Hence, this chapter conducts a multi-scalar climate vulnerability analysis in Ghana to identify vulnerable and resilient regions and districts, in which further local level studies are carried out to characterise the nature of vulnerability and determine adaptation pathways. It builds from analyses undertaken in other parts of the globe where data are more widely available and variability is not as marked (Simelton *et al.*, 2009) to highlight the value of initial broad-scale quantitative analyses as the starting point for more detailed, multi-method analyses of climate change vulnerability. This sort of methodological innovation is widely called for across the climate and development literature (Keskitalo, 2008; Yin *et al.*, 2002).

The IPCC characterises the vulnerability to climate change as a function of the exposure, sensitivity and adaptive capacity (IPCC, 2007). Assessing vulnerability, therefore, requires an integrated assessment across a range of disciplinary spheres and scales requiring new geographical assessment tools and frameworks. The aim of this chapter is to develop and apply a multi-scale quantitative approach to vulnerability assessment within Ghana to identify which of the country's regions and districts are most vulnerable and resilient to drought in relation to food production. To achieve this, the chapter objectives are to:

1. Develop a methodological approach for identifying vulnerable and resilient regions in relation to food production systems in Ghana;
2. Use rainfall, yield and socioeconomic data to evaluate the exposure, sensitivity and adaptive capacity of Ghana's regions and districts;
3. Reflect on the utility of using this sort of quantitative approach as a tool for use in other countries;

4. Explore the extent of climate change and variability in the identified resilient and vulnerable regions.

By meeting these objectives, this chapter develops geographical analysis tools that offer important new methodological opportunities. This chapter also has policy implications as it provides policy makers with appropriate information on vulnerability to feed into a more targeted climate adaptation policy in Ghana. What follows is an explanation of how rainfall, yield and socioeconomic data were used to develop drought vulnerability index through the conceptualisation of vulnerability as a function of exposure, sensitivity and adaptive capacity.

4.2 Developing a drought vulnerability index

The research presented in this chapter followed three stages that correspond to the following conceptualization of vulnerability (equation 4.1):

$$V = f\,(E+S-AC) \qquad (4.1)$$

In this equation, V is vulnerability of regions to drought, E is exposure to drought (reflected in the size of drought), S is the sensitivity of crop harvest to rainfall perturbations, and AC is adaptive capacity of regions to cope with drought (determined using socioeconomic proxy indicators).

The first stage of the research involved the determination of sensitivity of crop harvest to drought by creating a crop yield sensitivity index that made use of historic yield data at both national and regional scales. The second stage used existing rainfall data to estimate drought exposure at the same spatial scales by calculating national and regional level exposure indices. The third stage determined an adaptive capacity index by using proxy socioeconomic data available from the 2000 Ghanaian census.

4.2.1 Determining 'sensitivity' of crop harvest to rainfall perturbations

Sensitivity is inferred through the harvest losses associated with different droughts and is determined through the development of a crop yield sensitivity index. To determine the sensitivity of crop harvest to rainfall perturbations, a crop yield sensitivity index was calculated using methods adapted from Simelton *et al.* (2009). Yield data for maize for all 10 regions of Ghana were obtained from the national Ministry of Food and Agriculture, for the period 1992–2007. Maize was selected as the test crop because it is the main crop grown, being widely consumed as a staple across the country (Kasei and Afuakwa, 1991; Morris *et al.*, 1999). The period 1992–2007 was selected due to the availability of yield data.

This thesis followed processes of de-trending used by Lobell *et al.* (2007) and Easterling *et al.* (1996) whereby a linear model of the time series of the actual yield was removed from the data by dividing the projected linear trend value by the actual observed value. This was done to reduce the influence of increased agricultural technology in order to highlight inter-annual yield variation as a result of rainfall. According to Lobell *et al.* (2007), this is an important step that is required to explore the relationship between climatic factors and crop yield. To determine the crop yield sensitivity index, the linear trend for each yield for each region between 1992 and 2007 was calculated. The equation for this trend line was used to calculate the expected yield in each year. The expected yield was then divided by the actual yield for each year to generate a crop yield sensitivity index as per regional analyses previously applied in China (Simelton *et al.*, 2009) (see equation 4.2).

$$\text{Crop yield sensitivity index} = \frac{\text{Expected yield}}{\text{Actual yield}} \qquad (4.2)$$

4.2.2 Determining 'exposure' to drought

Exposure is defined as the degree to which a particular system is exposed to meteorological drought (Fraser, 2007; Tilahun, 2006) given that drought is the major threat to many African farming systems (UNDP, 2007). Meteorological data were used as a way of creating an exposure index that reflects the degree to which different farming regions were exposed to drought. The estimation of exposure to drought followed procedures developed by Simelton *et al*. (2009) for calculation of an exposure index. Monthly rainfall data were obtained from the Ghana Meteorological Agency for 1971–2007. A standard 30-year climatological period, from 1971–2000, was used to eliminate year-to-year variations and is considered adequate for agro-meteorological planning (Todorov, 1985). The maize growing period in Ghana is 126–

200 days between April and August and this period coincides with the moisture requirements during flowering (Kasei and Afuakwa, 1991). To develop the exposure index, the average of the 30-year rainfall period for the 5–month period (April–August) from 1971 –2000 was divided by each year's average rainfall for this period (April–August), which represents the growing season for maize (as shown in equation 4.3).

$$\text{Exposure index} = \frac{\text{mean long-term growing season rainfall for } 1971-2000}{\text{mean growing season rainfall for each year for } 1992-2007} \qquad (4.3)$$

Whilst data on the number of people that have been exposed to drought in the past in the study area are lacking, the thesis examined qualitatively the nature of agro-ecosystem in the study communities through ecological surveys (see Chapter 5) so as to account for the other dimensions of exposure, which include the entities under stress (see Polsky *et al.*, 2007). However, in terms of climate factors, this study considered only rainfall because it is the most critical hydrological variable for agricultural productivity (Tilahun, 2006). Sivakumar *et al.* (2005) have reported that significant reductions in crop yield have always been attributed to abnormally low precipitation-induced drought rather than warming-induced increases in evapo-transpiration rates.

4.2.3 Determining 'adaptive capacity' to cope with drought

Adaptive capacity is defined as the ability of a region to cope with the impacts of climate change and variability (particularly drought) and it is estimated by a set of proxy socioeconomic indicators. The adaptive capacity required to cope with drought is thought to depend on five livelihood assets: financial, human, natural, physical and social capital assets (Gbetibouo *et al.*, 2010). Two proxy indicators of adaptive capacity were considered: human capital (represented by literacy rates (%)) and financial capital (represented by poverty rates (%)). These proxy socioeconomic indicators were obtained from the census data by the Ghana Statistical Service (2000). These two proxy indicators (see equation 4.4) rather simplify the situation but were selected because they were the only indicators for which data were available for all ten regions. Nevertheless, they are considered to be appropriate in the literature (Gbetibouo *et al.*, 2010; Brooks *et al.*, 2005). In this study, natural capital is included in the sensitivity component of vulnerability and it is assumed that the greater the natural capital the less the sensitive the region to the impacts of drought. Social and physical capital assets are explored in subsequent phases of this multi-scale thesis using household and village level livelihood studies (see Chapter 5).

Adaptive Capacity = (Literacy Rate/100) + ((100-Poverty Rate)/100) (4.4)

Hence, the overall vulnerability of a particular region was estimated from the following:

Vulnerability = [(crop yield sensitivity index + exposure index) – adaptive capacity] (4.5)

4.2.4 Mapping crop drought vulnerability at the regional scale

The methods described above were used to map vulnerability at the national scale where proxy socioeconomic data were available. After identifying the most vulnerable and resilient regions the thesis then mapped food production vulnerability at the regional scale within those regions, to locate the most vulnerable and resilient districts. The relationship between climate variability and agricultural productivity is very complex. Whilst major changes in the climate over the years have resulted in relatively few changes in overall food production in certain agriculture-dependent communities, the literature abounds in describing situations where even slight climate variability has resulted in a significant reduction in the overall food productivity in other farming communities (Simelton *et al.*, 2009). Therefore, it was hypothesised that in situations where major droughts resulted in insignificant crop losses in a particular district then there may be underlying high levels of adaptive capacity, reflecting the socioeconomic conditions of the district. Such a district is considered ‘resilient’. In contrast, in situations where there were large losses in crop harvest following minor rainfall perturbations then there may have been underlying low levels of adaptive capacity that made such district ‘vulnerable’ (Simelton *et al.*, 2009). Due to the lack of proxy socioeconomic data at the regional levels, a crop drought vulnerability analysis following the procedures adapted by Simelton *et al.* (2009) was used to identify vulnerable and resilient districts within the most vulnerable and resilient regions (equation 4.6).

$$\text{Crop drought vulnerability index} = \frac{\text{crop yield sensitivity index}}{\text{exposure index}} \qquad (4.6)$$

The crop drought vulnerability index approach is useful as it uses rainfall and regional crop harvest data to identify vulnerable and resilient cases in geographical regions where there are limited proxy socioeconomic indicators with which to estimate adaptive capacity. In the regional level analysis, the thesis focused on food crops more associated with these vulnerable and resilient regions, (namely sorghum and millet for the vulnerable region and maize for the resilient region), for the construction of the crop yield sensitivity index. District boundaries have changed over the study period and this makes it difficult to have reliable data for this finer level analysis. This challenge was overcome by not considering districts that have recently had their borders changed. Once the overall mean vulnerability was calculated, a *k*-means cluster analysis using the Statistica software was undertaken to group the regions according to their vulnerability.

The limitation of this vulnerability assessment is acknowledged. This thesis has established the extent of drought vulnerability based on the spatial dataset obtained from the GMet and yield data from MoFA. Most of these datasets have quality issues. For instance, the yield data were estimated and not based on actual observed yield on the field. Adaptive capacity was only based on the proxy indicators where data were available for all the regions in Ghana. It is, therefore, greatly advised that caution should be exercised when interpreting the results of the vulnerability assessment. Nevertheless, this vulnerability assessment enables development project advice to be targeted at regions of greatest need in terms of vulnerability to future drought events.

4.3 Results

Figure 4.1 shows the overall crop yield sensitivity to drought of the various regions in Ghana. The analysis indicates that the Upper East and Upper West regions are the most sensitive in terms of exposure to drought. This is reflected in the extent of crop failure associated with meteorological drought in these regions. Farmers in these two regions mostly practise subsistence farming and are heavily dependent on rain-fed agriculture. Because of the inherent low soil fertility in these regions (e.g. Quansah, 2004), only certain types of crops (mainly cereals such as sorghum and millet) can thrive, and these crops require an appreciable amount of water during growth.

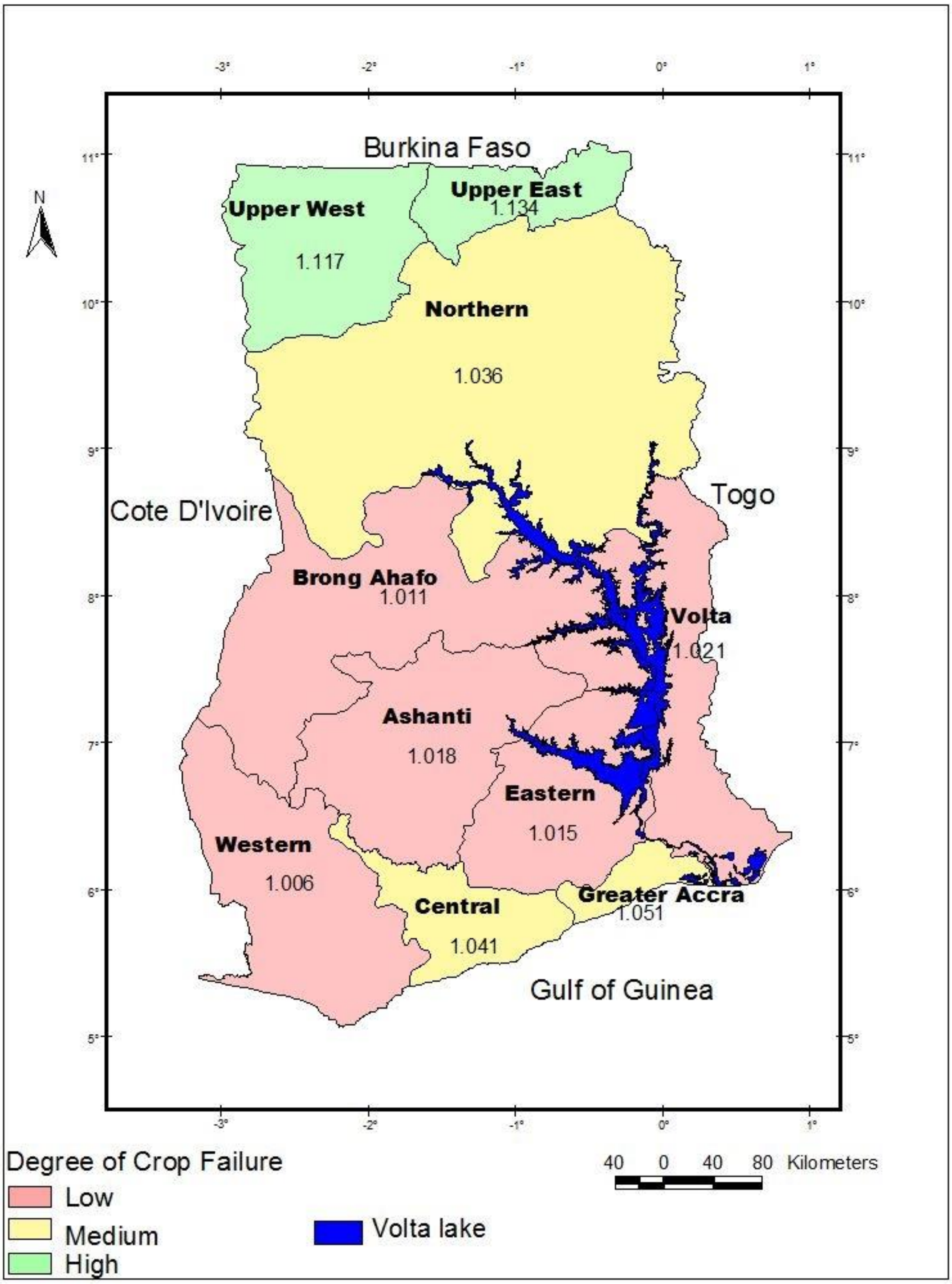

Figure 4.1**:** Crop yield sensitivity of the various regions in Ghana

The Northern region, Central and Greater Accra recorded moderate crop failures. With regard to drought intensity, Figure 4.2 shows that the majority of regions experienced medium levels of drought with the four regions of the south experiencing high levels of drought and the most northwest region experiencing a low level.

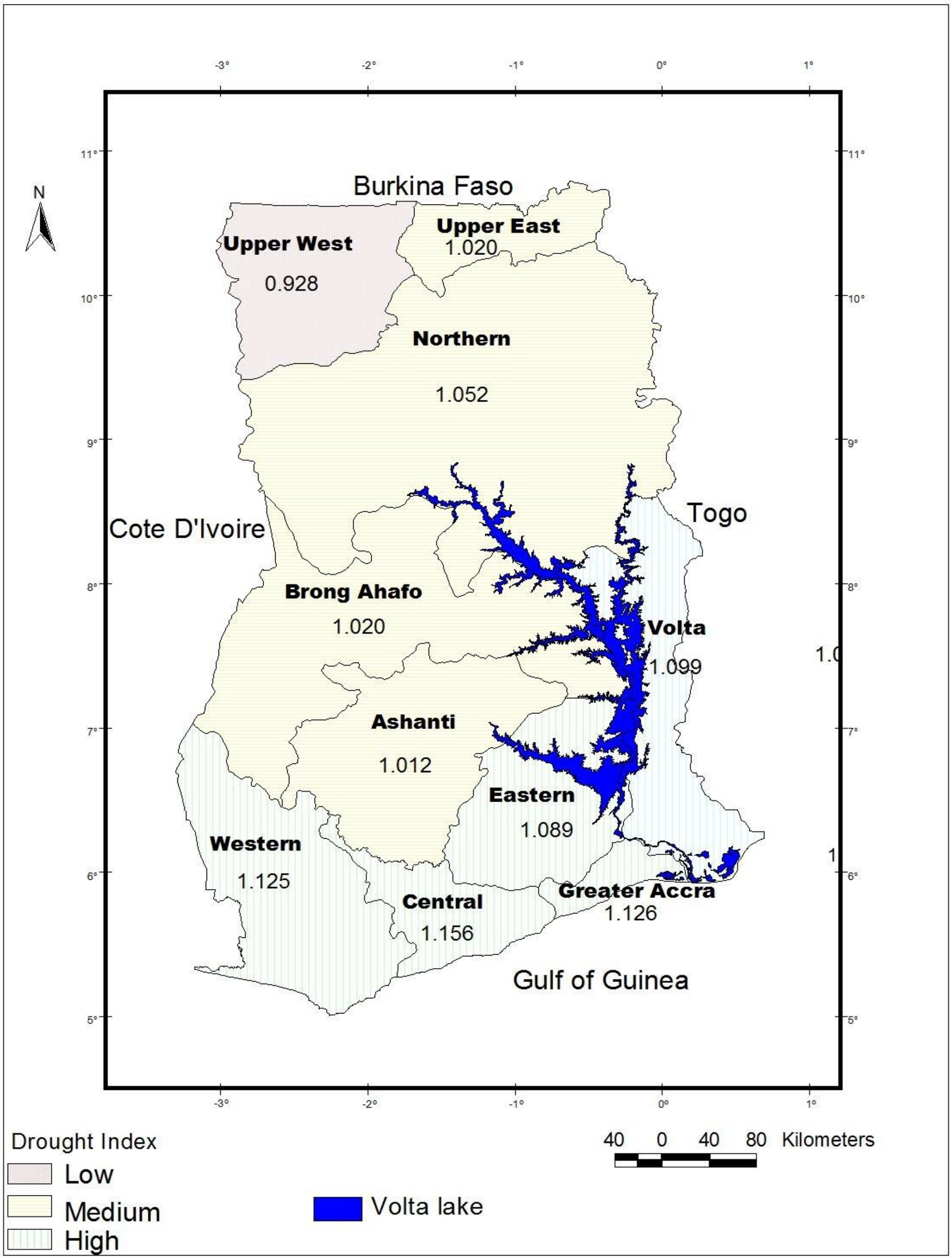

Figure 4.2: Exposure of the various regions in Ghana

The overall adaptive capacity for the various regions is shown in Figure 4.3. The Northern, Upper East and Upper West regions show the lowest values, suggesting that these regions have the lowest capacity to cope with drought. These regions are characterised by high poverty levels coupled with low infrastructural development (GSS, 2000). The Greater Accra and the Ashanti regions show the highest adaptive capacity (Figure 4.3).

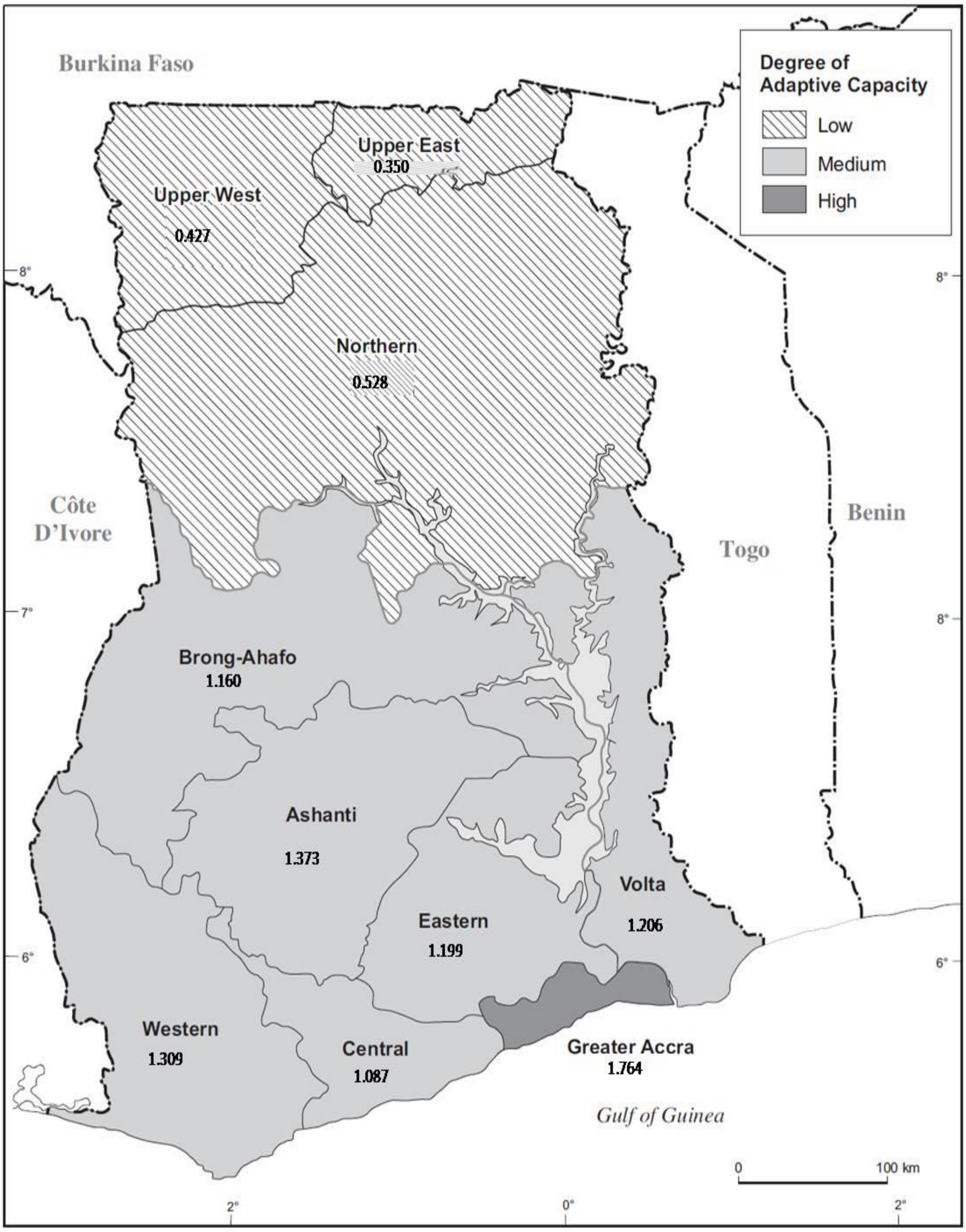

Figure 4.3: Adaptive capacity indices of the various regions in Ghana

Figure 4.4 shows the result of the k-means cluster analysis and demonstrates that there are three different clusters according to vulnerability: half of the regions in Ghana are moderately vulnerable to drought, whilst a third is highly vulnerable and only two regions have low vulnerability. Figure 4.5 presents this analysis spatially, showing that the Northern, Upper East and Upper West regions are the most vulnerable to drought while the lowest vulnerability regions are the most urbanized and developed regions:

Ashanti and Greater Accra. The three northern regions – Northern, Upper East and Upper West regions – that belong to the high vulnerability cluster recorded the lowest adaptive capacity. These three regions are also located in the most northern parts of the country. By contrast, the least vulnerable regions – Ashanti and the Greater Accra regions are characterised by relatively better socioeconomic conditions and thus, recorded the highest adaptive capacity. In between these two vulnerability clusters are the regions that experienced moderate vulnerability (Brong Ahafo, Central, Western, Eastern, and Volta regions).

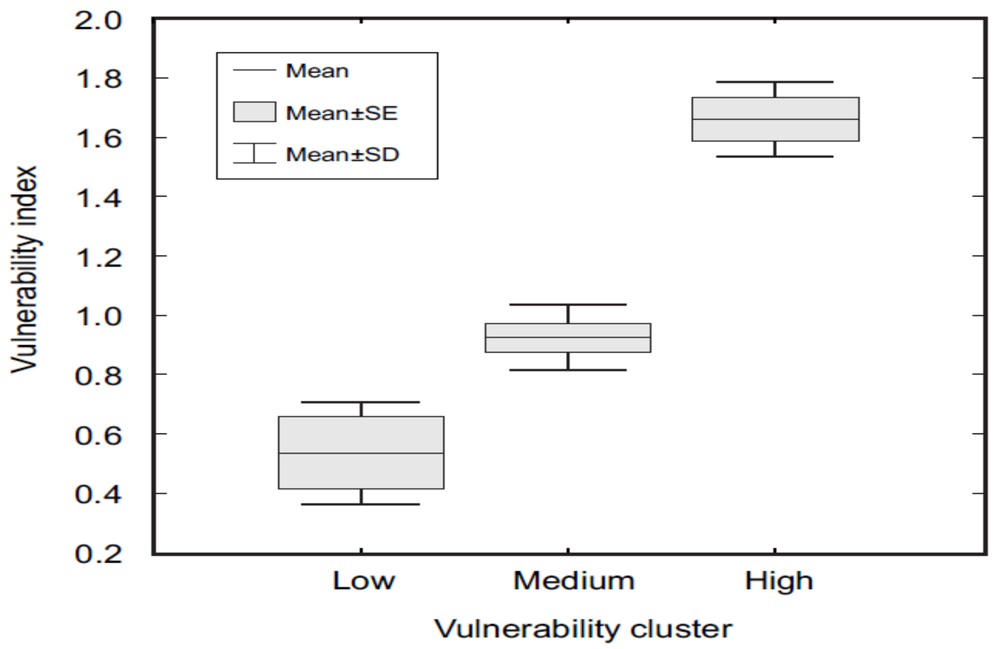

Figure 4.4: Box and whisker plot of vulnerability clusters derived by k-means cluster analysis

Figures 4.6, 4.7 and 4.8 provide a regional level breakdown for the three most vulnerable regions – Upper East, Upper West and Northern – respectively. In general, millet recorded high vulnerability indices in all the districts within the three most vulnerable regions compared with sorghum except in the Bawku West district in the Upper East (Figure 4.6), Wa district in the Upper West (Figure 4.7) and Saboba and Zabzugu districts in the Northern region (Figure 4.8). The districts within the Northern regions recorded the lowest vulnerability indices compared with the Upper East and West regions for all crops during the study period. Gambaga and Damongo in the Northern regions recorded the lowest vulnerability indices for both millet and maize (Figure 4.8).

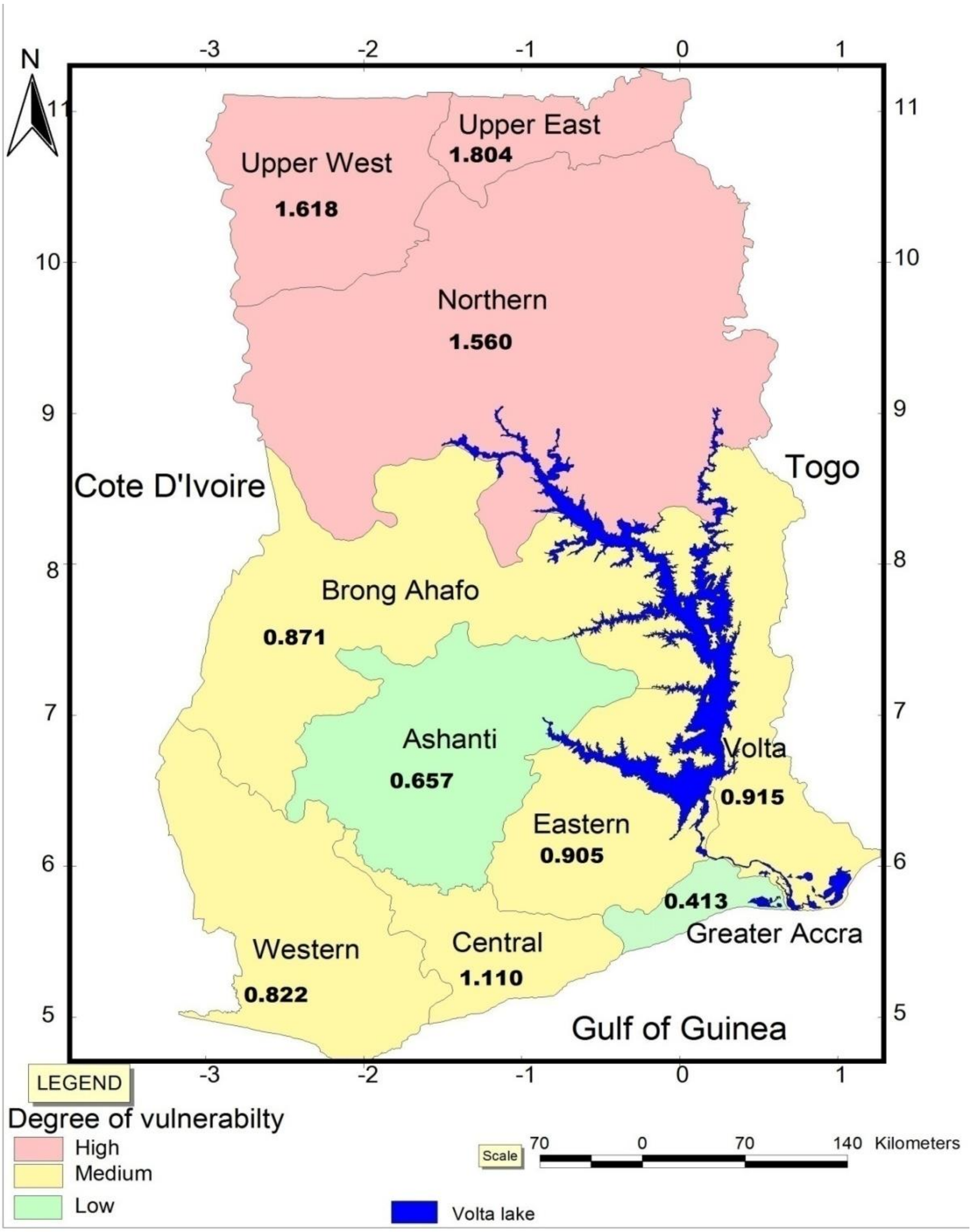

Figure 4.5: Vulnerability indices of the various regions in Ghana

While the standard errors within the data are large, the general trend is that the districts in the Upper East region recorded higher mean vulnerability indices for both sorghum and millet compared with those in the Northern and Upper West regions. Within the Upper East region, the Bongo district recorded the highest mean vulnerability index for the investigated period (Figure 4.6) and, therefore, was selected as the most vulnerable district where case study villages were selected to assess the vulnerability of food production systems at the village and household levels.

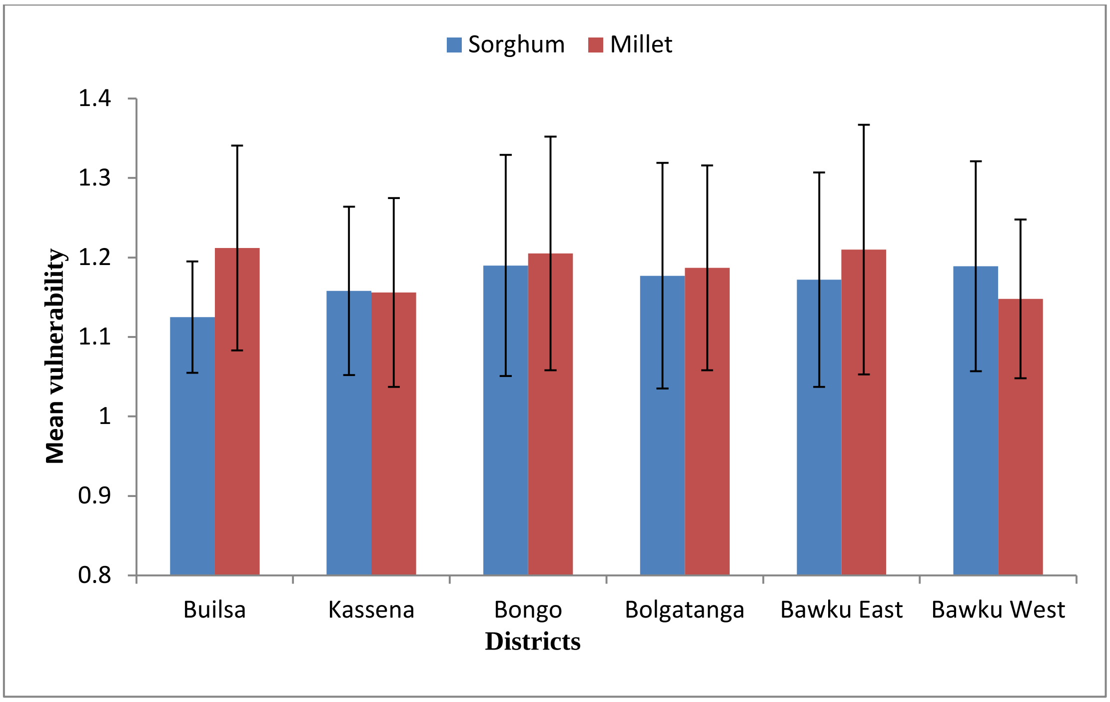

Figure 4.6: Mean vulnerability indices of districts in the Upper East region, Ghana

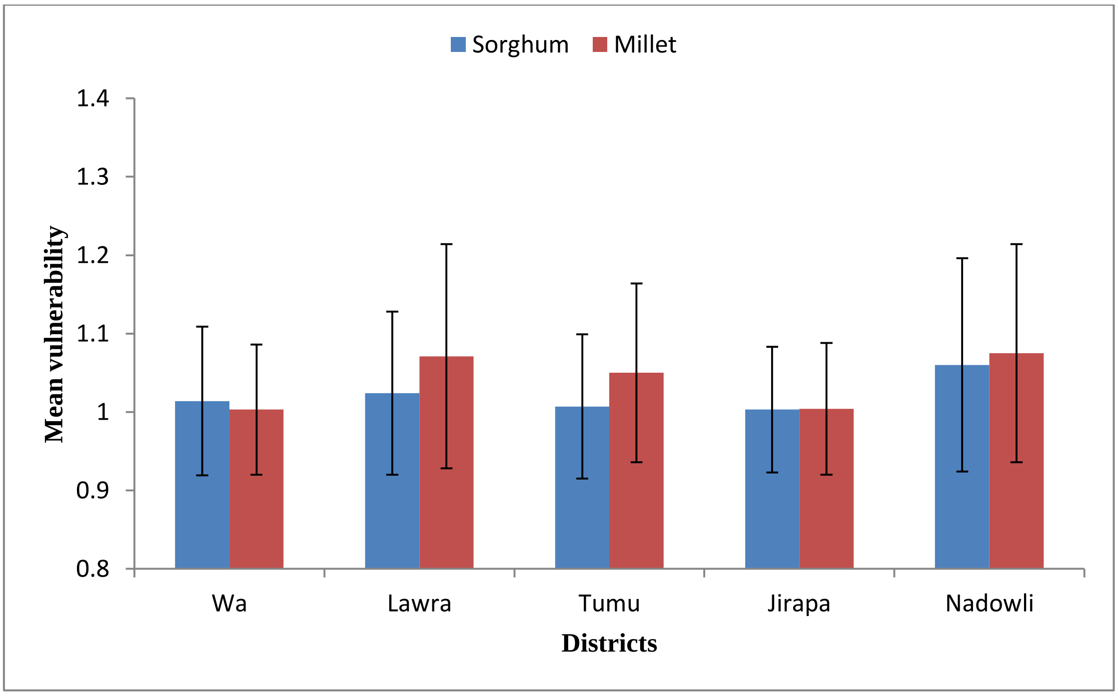

Figure 4.7: Mean vulnerability indices of districts in the Upper West region, Ghana.

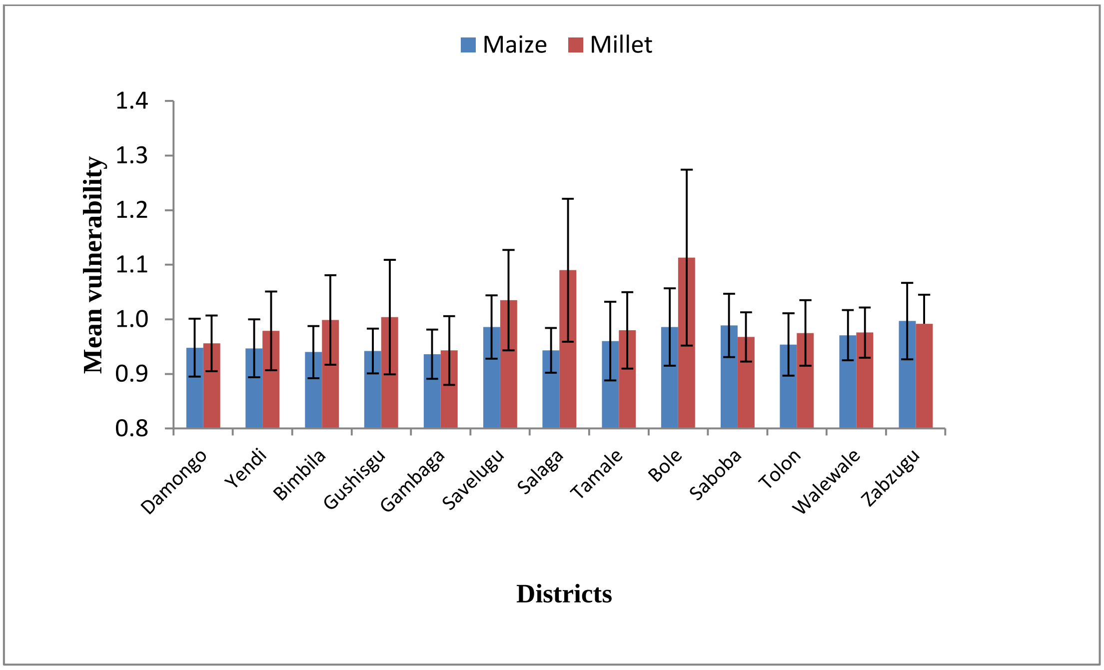

Figure 4.8: Mean vulnerability indices of districts in the Northern region, Ghana

The Ashanti and the Greater Accra regions recorded the lowest vulnerability scores overall, making them the two least vulnerable (or most resilient) regions in Ghana (Figure 4.5). This is reflected in the adaptive capacity as well as the extent of crop failure associated with drought in these two regions. The relative high adaptive capacity of these two regions is further reflected in high literacy rates, alternative livelihood options and relative low poverty rates that enable drought-related problems to be coped with more competently than in other regions. In addition, these two regions have better infrastructural development, access to financial services (banking and non-banking institutions), and better access to social networks.

The Ashanti region was nevertheless selected ahead of Greater Accra region as the least vulnerable (i.e. most resilient) region because the Ashanti region has been a traditional food producing area, growing a significant amount of the food consumed nationally (MoFA, 2007). In addition, the Ashanti region is located within the transitional and semi-deciduous forest zones in terms of agro-ecological zone (see Figure 3.2 and Table 3.2). The transitional zone shares the features of both the savannah and forest zones and holds great potential for food security, including the production of staples such as maize and yam (Morris *et al.*, 1999). The Ashanti region shares features of two different agro-ecological zones and hence, makes an interesting case for the resilient case study districts and communities. Within the Ashanti region, there were no significant statistical differences amongst the various districts (Figure 4.9). The Ejura Sekyedumase district was selected because it is one of the major food producing districts in Ghana. Furthermore, because of the unique agro-ecological features of the district as it is located within the transitional zone of the country, there are a number of governmental and non-governmental projects. Thus, it provides interesting case study communities in which to explore the research objectives. Within one resilient (Ejura Sekyedumase) and one vulnerable district (Bongo district), 6 specific resilient and vulnerable farming communities (3 in each case) were selected for further local level research, based on information gained through interviews with experts and stakeholders (see Chapter 3 for full details on this).

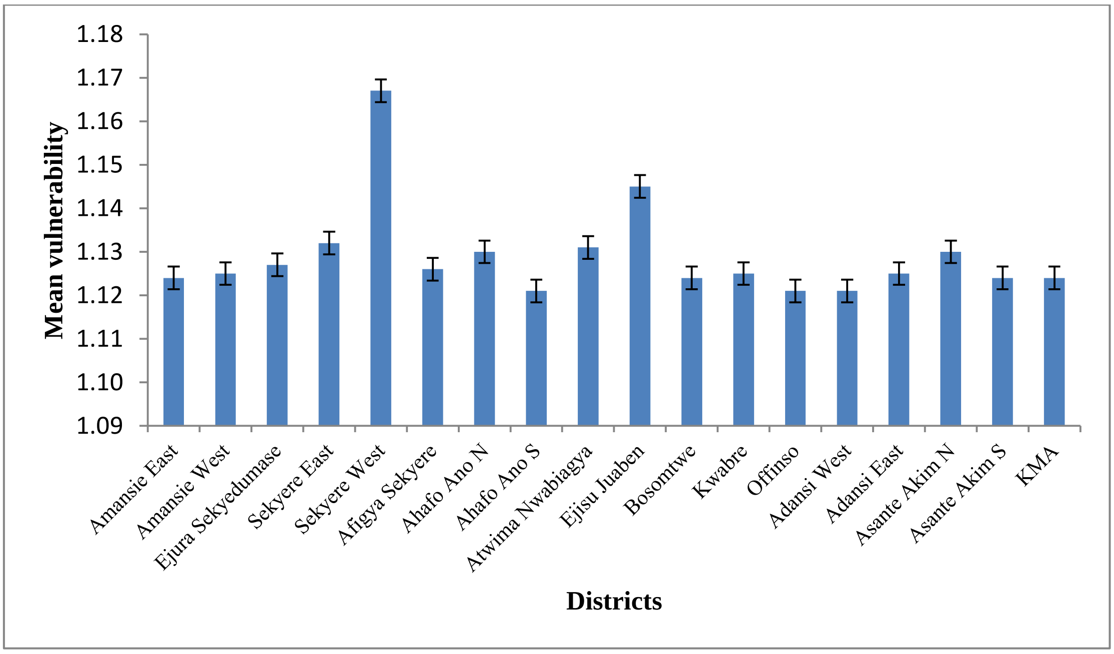

Figure 4.9: Mean vulnerability of maize of districts in the Ashanti region, Ghana.

Having selected these regions and districts through quantitative vulnerability assessment at the national and regional scales, Section 4.4 presents data to show the extent of climate change and variability in the selected regions and districts.

4.4 Establishing the extent of climate variability in the study regions

To assess the extent of climate change and variability in the identified study regions, a time series analysis of climate (rainfall and temperature) data obtained from the Ghana Meteorological Agency (GMet) was conducted.

4.4.1 Evidence of rainfall variability in the study regions

Climatic data from 1961–2007 from the GMet show that there have been some hydro-climatological changes within the study regions. The climate time span was limited to 46 years (from 1961–2007), due to restrictions on the availability of climatic data. However, this period is considered adequate to allow the establishment of the extent of interaction between livelihood context and climate variability in the study regions. Within the resilient region, Figure 4.10 shows that the amount of rainfall was quite substantial from 1961 until 1968 when the region recorded its highest rainfall of 2344 mm. Rainfall patterns have shown variability since this period.

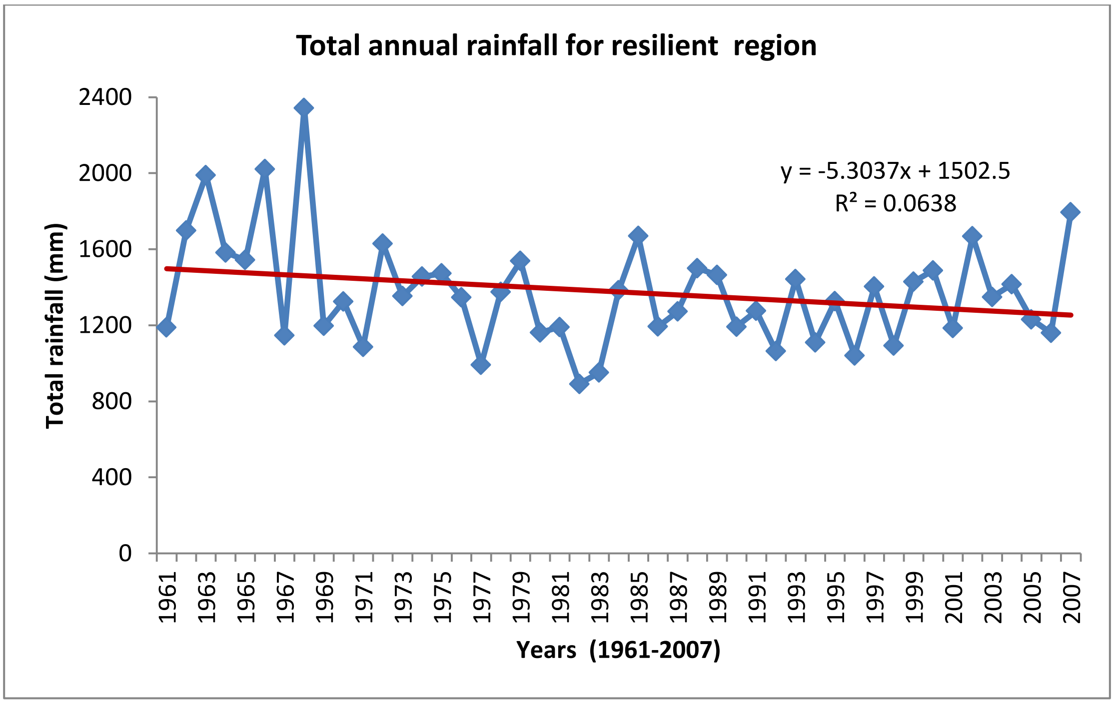

Figure 4.10: Annual rainfall for the resilient regions (1961–2007).

Source: Data from the Ghana Meteorological Agency.

Figure 4.11 shows that there has been rainfall variability in the vulnerable region (i.e. Upper East region). For instance, the vulnerable region recorded the lowest rainfall amount of 671 mm in 1977, followed by a series of erratic rainfall patterns until 1999 when the area recorded its highest rainfall amount of 1365 mm (Figure 4.11). According to the regional MoFA in the Upper East region (i.e. vulnerable region), at least 950 mm of rainfall is required for crop production (see Assan *et al.*, 2009). Hence, using 950 mm as the baseline, there has been 20 years over a period of 46 years that could be considered risky for crop production (Figure 4.11). Data from the Ghana

Meteorological Agency suggest that within the Upper East region there have been major drought seasons in 1961, 1974–77, 1981, 1983–84, 1991, 1993, 1995. Since 2000 there has been three major drought seasons including 2002, 2005 and 2006.

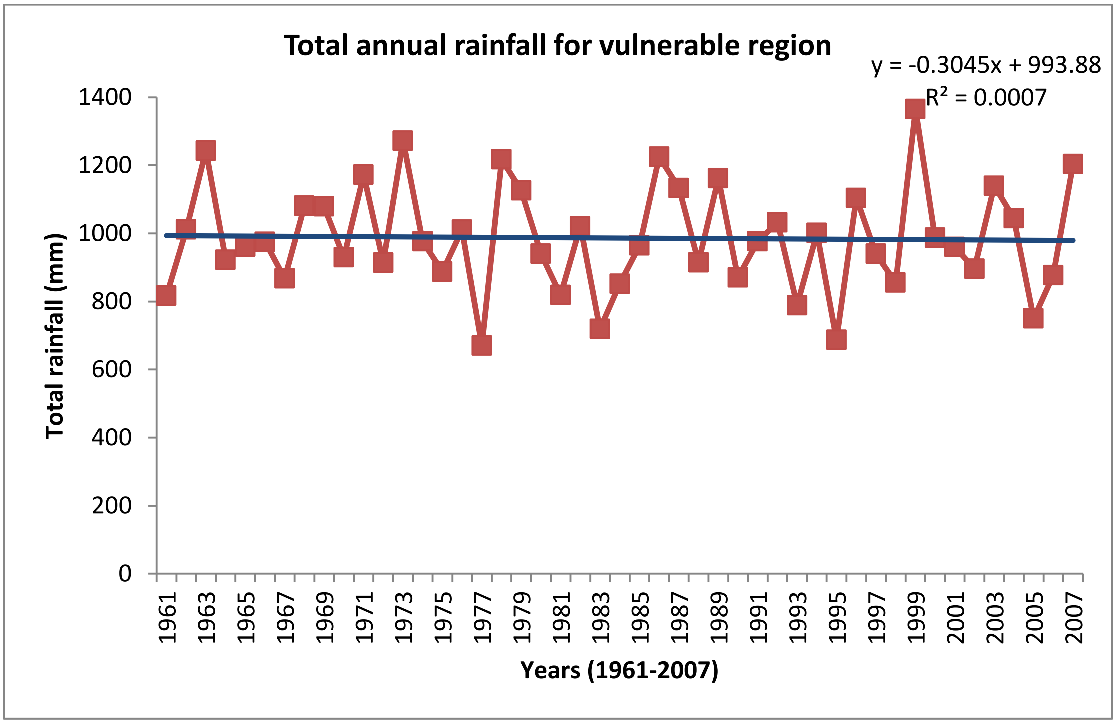

Figure 4.11: Annual rainfall for the vulnerable regions (1961–2007).
Source: Data from the Ghana Meteorological Agency.

The reduced precipitation in the study regions lends more credence to other studies that suggest that there has been remarkable decline in the amount of rainfall in Africa, particularly SSA (Boko *et al.*, 2007; Nicholson, 2001; Hulme *et al.*, 2001). Though the general prediction of the rainfall patterns in Africa has been less consistent compared with projections in temperature (Hope, 2009), the general agreement is that there will be a decline in rainfall in most parts of SSA. The fact that there is more rain in the resilient region and less in the vulnerable region is in keeping with the expectation given that these regions are in different agro-ecological zones (Figure 3.2). Nevertheless, the decline in rainfall is more stark in the resilient region. It is worth emphasising that for farmers it is not just the amount of rain that is important, but when it comes, and when they plant in relation to the rains (Ingram *et al.*, 2002).

4.4.2 Evidence of temperature changes in the study regions

Temperature, another important element of climate that is critical for agricultural productivity in the tropics, was also assessed (Lobell and Burke, 2008). A time series analysis of minimum and maximum annual temperatures in the study regions shows that there have been changes in annual temperatures over the four and half decades from 1961–2007. Within the resilient region, Figure 4.12 shows that there has been an increase in the maximum mean annual temperatures over the period from 30.2°C in 1961 to 31.8°C in 2007, representing an increase of 1.6°C in the maximum mean annual temperatures. The vulnerable region recorded an increase of 0.7°C.

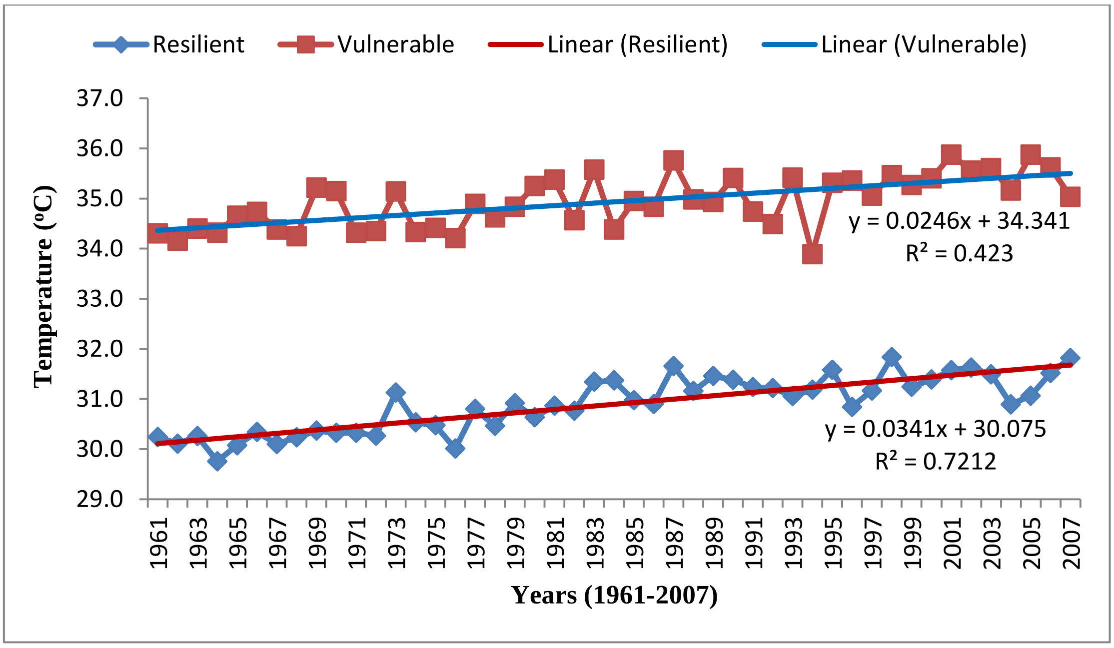

Figure 4.12: Mean annual maximum temperature for study regions (1961-2007). Source: Data from the Ghana Meteorological Agency.

A similar trend is observed for the minimum annual temperature in both resilient and vulnerable regions. Figure 4.13 shows that there have been changes in the minimum air temperature with 21.1°C in 1961 to 22.0°C in 2007, representing an increase of 0.9°C for the resilient region. In terms of minimum annual temperatures in the vulnerable region, Figure 4.13 further shows a mean minimum temperature of 22.0°C in 1961 and 23.0°C in 2007, which represents an increase of 1.0°C. Indeed, several studies have confirmed the increasing temperature trend in most parts of Africa (e.g. Hulme *et al.*, 2001; Boko *et al.*, 2007; Christensen *et al.*, 2007).

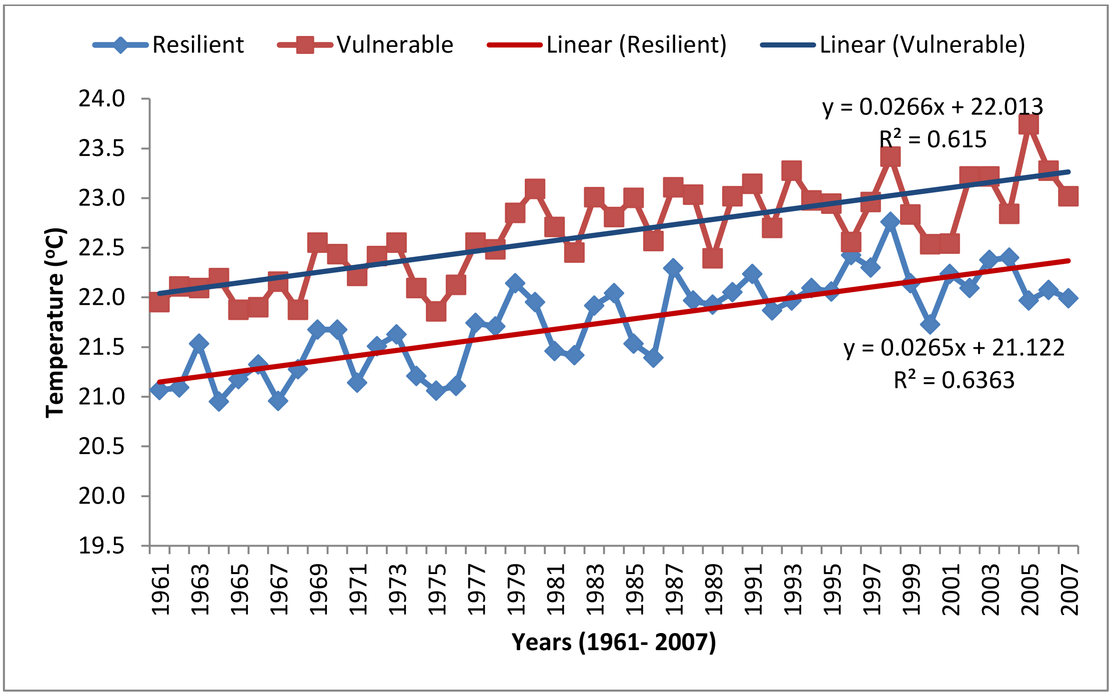

Figure 4.13: Mean annual minimum temperature for the study regions (1961-2007)
Source: Data from the Ghana Meteorological Agency.

4.5 Discussion

The results show that there are strong spatial and socioeconomic patterns in terms of vulnerability of crop production to drought in Ghana. In particular, results suggest that the vulnerability of the regions is highest in the Northern, Upper West and Upper East regions (Figure 4.5) and that these are characterised by low levels of social, economic and physical assets (GSS, 2000). Even within these vulnerable regions, there was different vulnerability among the various districts that could partly be attributable to socioeconomic as well as biophysical factors. For instance, the Bongo district (Upper East region) recorded the highest average vulnerability index due to the high poverty level and low literacy rates in the region in general and the Bongo district in particular.

The major crops grown in the study area include maize, cassava, plantain, rice and yam in southern Ghana and, millet, sorghum, guinea corn and maize in northern Ghana (MoFA, 2007; Kasei and Afuakwa, 1991). These crops require an appreciable amount of water during growth and persistent droughts, especially in the most vulnerable regions (i.e. Northern, Upper East and Upper West) have often resulted in low production from such crops. Indeed, soils in the Upper East region and the Bongo district in particular are characterised by stoniness and gravel and these, together with iron-pan in the soils, make them highly unproductive and poor at retaining moisture (Quansah, 2004). These soils are also deficient in nitrogen, phosphorus and sulphur (Oteng et al., 1990). Hence, most of the food crops that thrive in the southern part of the country do not do well in the Upper East region as there is limited rooting depth that makes the production of deep rooted crops quite difficult. Continuous cropping of farm lands in the Upper East region without the addition of appropriate soil amendments has left the soil with low fertility and in a highly unproductive state. High poverty levels in the Upper East region make it difficult for farmers to afford fertilizers to improve soil fertility. In addition, low socioeconomic development and erratic rainfall patterns (in terms of both onset and duration) make farmers in the Upper East region in general, and the Bongo district in particular, extremely vulnerable to the adverse impacts of climate variability and change. This is because the major occupation in this district is rain-fed agriculture (MoFA, 2007).

Poverty can lead to marginalisation and limit the capital assets that may be needed to reduce the impacts of drought on livelihoods of farming communities (Adger and Kelly, 1999) such as those in the Northern, Upper West and Upper East regions. For example, an estimated 90%, 80% and 70% of people in the Upper East, the Upper West and the Northern regions respectively are considered to be poor (GSS, 2000). Though poverty may not be directly equated with vulnerability, it could potentially constrain the capability of communities to cope with the impacts of drought and this is especially so for rural areas such as Bongo district where livelihoods depend entirely on rain-fed agriculture (Sen, 1999). In addition, the poor are confronted with other non-environmental shocks and stresses such as economic and political pressures that place additional constraints on their limited assets to cope with the impacts of drought (Stringer *et al.*, 2009).

Moreover, poverty may compel people to live in environmentally fragile areas which could worsen their vulnerability to climate and other environmental changes (Adger, 2006). Hence, high poverty levels in these vulnerable regions will further inhibit the potential of such small-holder poor farmers to manage the impacts of climate variability. Also, differences in land tenure between northern and southern Ghana could partly contribute to the vulnerability of the three regions in the north: Upper

East, Upper West and Northern regions (how land tenure influences the vulnerability of farming households in northern and southern Ghana are explored in greater detail in Chapters 5 and 7).

The results from this study further reveal that the Guinea savannah and Sudan savannah agro-ecological zones are the most vulnerable to increasing drought events in Ghana (see Figure 3.2 and Figure 4.5). These zones experience a uni-modal rainfall pattern and are predominantly characterised by drier conditions and fragile agro-ecosystems. As a result, these types of regions are also likely to be vulnerable to climate variability and change. Soils within the Guinea and Sudan savannah agro-ecological zones have poor fertility that, together with desertification, exacerbates food insecurity (EPA, 2003).

The results support the findings of Gbetibouo *et al.* (2010) for South Africa that indicate that the vulnerability of a farming region to drought is linked to the socioeconomic development characteristics of that particular region. Vulnerability is greatly influenced by the degree of development and socioeconomic status of a particular group or community (Gbetibouo *et al.*, 2010). Hence, the ability of an area to cope with the impacts of climate change is reflected in the assets and entitlements that can be assembled to reduce vulnerability (Moser, 1998). It is well documented that the entitlements of individuals to capital assets including financial, human, natural, physical, and social capitals could affect their ability to cope with the impacts of climate variability and change (Sen, 1981). For instance, human capital assets such as education can enhance adaptive capacity (e.g. Brooks *et al.*, 2005) by increasing the income earning opportunities of rural households whose livelihoods depend on agriculture (these capital assets are explored in detail in Chapter 5 at the community and household levels).

Declining precipitation in the study regions coupled with future predictions of annual temperature increases (EPA, 2007; Christensen *et al.*, 2007) presents serious challenges to farmers in these regions since they depend entirely on rainfall for crop production and other rural livelihoods (see Chapter 2). Increasing temperature increases evaporation and evapo-transpiration that leads to a reduction in soil moisture content. Even though temperature is important for crop production, rainfall may be more critical for crop production in the tropics (Sivakumar *et al.,* 2005). Perhaps, this may be attributed to that fact that a lack of or excess of rainfall over a period can potentially lead to either drought or flooding that can reduce crop production and hence lead to food shortage (see Haile, 2005). This is important given that farming activities in the study regions are dependent on rainfall. Indeed, drought is the major threat to African farming systems (UNDP, 2007). Hence, in Ghana and most parts of SSA, the pattern and duration of the rainfall are significant determinants of crop productivity (Haile, 2005; Lobell and Burke, 2008). A study by Mertz *et al*. (2010) in five African countries including Mali, Senegal, Nigeria, Niger and Burkina Faso suggests inadequate rainfall distribution is perceived by farmers to be one of the main causes of decline in crop productivity in rain-fed agriculture. Reduced precipitation could also adversely affect the water inflow into water bodies in the study areas. Water resources are under stress from population increase and economic development but climate change will compound this situation (Hanjra and Qureshi, 2010). This will place food security and rural livelihoods in Ghana under considerable stress.

4.6 Conclusions

This chapter has developed and applied a quantitative, multi-scale and multi-indicator analysis that has identified the relative vulnerabilities of the various regions in Ghana, as well as the relative vulnerabilities of different districts within the most vulnerable and resilient regions. The proposed spatially-explicit methodology is integrative in that it shows both the biophysical conditions of these farming regions by way of an exposure index and a crop yield sensitivity index whilst considering the socioeconomic conditions of the regions. Vulnerability has been expressed as a function of exposure, sensitivity and adaptive capacity (IPCC, 2007). Exposure was determined by developing an exposure index, whilst sensitivity was estimated through construction of a crop yield sensitivity index. Proxy indicators including poverty levels and literacy levels were used to estimate the adaptive capacity of the various regions in Ghana, thus extending the methodology employed by Simelton *et al.* (2009).

The analysis shows that vulnerability to drought is linked to the level of socioeconomic development and is spatially differentiated. This suggests the need for region- and district-specific climate adaptation policies, as different regions, and the districts within them, display different levels of vulnerability. The farming communities in the most vulnerable regions (including Northern, Upper East and Upper West) largely depend on rain-fed agriculture, a key livelihood activity that is very sensitive to climate change. Thus, livelihood diversification strategies including non-farm income sources should be vigorously pursued by policy makers in these regions. The implication of the results presented in this chapter is that policy makers need to formulate more specific and targeted climate adaptation policies to reduce the vulnerabilities of farmers whose livelihoods depend largely on rain-fed agriculture. Ultimately, this will enhance drought preparedness within dryland farming regions and communities. The approach outlined in this chapter is particularly useful in evaluating the vulnerability of a particular region or community to drought in developing countries where data for proxy socioeconomic indicators of exposure, sensitivity and adaptive capacity may be less readily available.

The next phase of this thesis is to characterise and explain the nature of vulnerable and resilient households and communities (i.e. Chapter 5) and determine the adaptation pathways of individual households to climate variability and change at a local-scale (i.e. Chapter 6). In this regard, the quantitative, national-scale analysis presented in this chapter enabled the identification of case study districts within the vulnerable and resilient regions, from which study villages were chosen using expert interviews and village level census data (where this exists), as outlined in Chapter 3. The findings presented here, however, go beyond simply setting up the next phase of more in-depth research. They enable policy and development project advice and extension activity to be focused on areas of greatest need in terms of vulnerability to climate change and future drought events.

CHAPTER 5

CHARACTERISING THE NATURE OF HOUSEHOLD VULNERABILITY TO CLIMATE VARIABILITY[12]

Summary

This chapter develops and applies a livelihood vulnerability index at the community and household scales to explore the nature of climate vulnerability. It provides innovative methodological steps in relation to livelihood assessment to identify the vulnerability of households and communities to drought. This will help to improve drought vulnerability assessments in Ghana and more widely as it shows extra information can be obtained from local-level vulnerability assessment that may be lacking in national- and regional-level analysis. This chapter employs quantitative and qualitative data collected through participatory methods, key informant interviews and a questionnaire survey. Results show that within the same agro-ecological zone, households and communities experience different degrees of climate vulnerability. These differences can be largely explained by socioeconomic characteristics such as wealth and gender, as well as access to capital assets. Results identify vulnerable households within resilient communities as well as more resilient households within vulnerable communities. These outliers are studied in detail. It is found that outlier households in vulnerable communities have an array of alternative livelihood options and tend to be socially well-connected, enabling them to take advantage of opportunities associated with environmental and economic changes. To sustain and enhance the livelihoods of vulnerable households and communities, policymakers need to identify and facilitate appropriate interventions that foster asset building, improve institutional capacity as well as build social capital.

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[12]This chapter is developed from the published journal article of Antwi-Agyei, P., Dougill, A.J., Fraser, E.D.G., and Stringer, L.C. (2012) Characterising the nature of household vulnerability to climate variability: empirical evidence from two regions of Ghana. *Environment, Development and Sustainability*. DOI 10.1007/s10668-012-9418-9.

5.1 Introduction

This is the first of three chapters that consider vulnerability and adaptation at the community and household levels. This chapter characterises and explains the nature of resilient and vulnerable livelihoods at both community and household levels. Empirical evidence on the generic characteristics of agriculture-dependent communities that have proven resilient or vulnerable to past climate-related problems is lacking at these scales. Addressing this gap will increase our understanding of how communities cope with the impacts of climate-related problems, providing useful insights into the structure and drivers of vulnerability (e.g. Eakin and Bojorquez-Tapia, 2008). This will provide valuable lessons for the management of climate variability in agriculture-depenedent communities in developing countries such as those in SSA more widely. The overall aim of this chapter is to explore the characteristics associated with those households and communities that are resilient and vulnerable to climate variability. This will help us to understand the processes and factors that create vulnerability, allows input from the studied communities themselves, as well as providing guidance for the development of effective policies. To achieve this aim, the specific objectives of this chapter are to:

a. Develop and apply a household livelihood vulnerability index in relation to climate variability (particularly drought) in order to compare and contrast the components of vulnerability in different case study farming communities.
b. Explore the socioeconomic, environmental and community characteristics associated with resilient and vulnerable households and communities by:
   (i) Exploring the differences in vulnerability index between the study communities;
   (ii) Exploring how two key factors, gender of the household head and wealth, affect the overall vulnerability of households;
   (iii) Examining the characteristics of each household and showing how these different characteristics contributed to the vulnerability score;
   (iv) Using statistical methods to identify “outlier households” to explore the drivers and structure of vulnerability at the household level.

In doing so, this chapter seeks to provide an empirical understanding of food production and rural livelihoods vulnerability at the household and community levels that will help guide a more general discussion of the sorts of food production systems and livelihoods that enhance adaptive capacity to future climate changes.

5.2 Choosing indicators of household livelihood vulnerability

One way the data described in Chapter 3 (Section 3.10.5) was used was to create a livelihood vulnerability index at the household level. The sustainable livelihoods approach (SLA, see Section 2.5.2) (Scoones, 1998) was used to frame the identification of indicators that determine household livelihood vulnerability. During focus group discussions and questionnaire surveys (Chapter 3), households were asked to highlight indicators linked to each form of capital asset (i.e. human, financial, natural, physical and social capitals) (see Appendices I and II). An assessment of livelihood capitals offers the opportunity to identify the various capacities that might be used to reduce rural communities' vulnerability to declining crop yields due to drought, and also how such declining yields can affect livelihoods (Ziervogel and Calder, 2003). The key indicators that emerged from this exercise were cross-checked with those mentioned in the literature (Yohe and Tol, 2002; Brooks *et al.*, 2005; Smit and Wandel, 2006). Table 5.1 shows the main indicators that were considered in this thesis after the literature review. What follows is a brief description of how the livelihoods assets were characterised in relation to households' ability to adapt to climate variability with a view to using this information to develop a livelihood vulnerability index at the household and community levels before results are presented and discussed.

5.2.1 Social capital

Social capital – including connections to technical support and social resources such as networks, associations and affiliations – was assessed by counting the number of associations or groups to which the members of the household belong (Pretty and Ward, 2001; Vincent, 2007). These include both formal and informal associations such as community-based organisations, farmer-based associations and faith-based associations (Scoones, 1998). It was assumed households that belong to more social groups and associations are better networked to cope with the impacts of climate change and variability on their livelihoods activities (Pretty, 2003; Adger, 2003), as these represent social safety nets and a form of informal grassroots insurance available to the household during climate-related crisis (e.g. Fraser, 2007; Vincent, 2007).

Membership of such associations also typically reflects the economic well-being of the household as it was discovered during FGDs that membership of the associations often involved the regular payment of dues (see Vincent, 2007).

Both bonding and bridging social capital were assessed. Bonding social capital is based on some exclusive characteristics such as family kinship, ethnicity or nationality (Woolcock, 2001). Bonding capital is defined by very high level of trust and interaction among members in such groups (Woolcock, 2001). Bridging capital refers to ties external to group boundaries and usually transcends socioeconomic status, nationality, religion, and ethnicity (Woolcock, 2001). Unlike bonding capital, bridging capital is often characterised by low levels of trust among members and less frequent interaction (Madhavan and Landau, 2011). A scoring procedure for social capital followed the methods of Vincent (2007). A score of 1 was afforded to households that belonged to no identifiable group, 2 for those who were members of one group, 3 for membership of two groups and 4 for cases where households belonged to three or more groups. While the level of interaction among the group members and the strength of the ties within social groups could affect their usefulness, interactions and ties were beyond the scope of the assessment and were not considered. Access to climate information could reduce households' vulnerability to climate variability (Ziervogel and Calder, 2003). Hence, households with access to climate information were scored 2 and those without were scored 1. Having access to extension advice is crucial in coping with drought in dryland farming systems. Thus, households with access to extension advice were scored 2 and those without access scored 1.

5.2.2 Human capital

Human capital assets are represented in two ways: by the educational level of the head of the household (or the most educated person in the household) and by the health status of the household. Rakodi (1999, p. 332) observes that "basic education is regarded as important in breaking the cycle of intergenerational poverty." To assess educational levels, four categories were used; no formal education was accorded a value of 1; 2 in the case of only primary education; 3 in the case of secondary education and; 4 for households that had tertiary education.

As there is a link between health and climate change, it is assumed that households with significant health problems will have lower human capital as they must allocate a substantial part of their scarce resources to treating illness (Patz *et al.*, 2005). Using part of the households' limited funds to treat illness will erode their financial asset base, thereby reducing capacity to withstand the impacts of climate change and variability. Since food production is labour intensive in the study communities, ill-health due to increased incidence of diseases linked to climate change and variability could adversely affect farm labour (Confalonieri *et al.*, 2007) because households with significant health problems during the farming season could miss crucial timelines that render crops more susceptible to drought. To assess health status, households were asked about the number of times they have been to the hospital (or hospitalised) within the last 12 months. Households with members that had been to the hospital were scored 1 whilst those with members that had not been to hospital as out-patients (and those not needing any medical attention) within this period were scored 2. Also, situations where members of a household required hospital treatment but could not arrange transport and other resources needed were taken into consideration when scoring such a household.

5.2.3 Natural capital

Natural capital assets consist of natural flow and stocks, land, and biological resources such as trees and biodiversity (Scoones, 1998). Natural capital assets were assessed by two indicators. The first was the size of the farm holding under cultivation (this was estimated as the average area of cultivated land over the past 5 years). It is assumed that the larger the farm holding, the greater the opportunity for the household to have more crops and yield, and hence the lower the vulnerability to climate variability. It is worth stressing that a household with a larger farm holding may be more dependent on agriculture and therefore more vulnerable than someone with a small area of land under cultivation but who works as a bus driver or a teacher. Households which cultivated less than 5 acres scored 1; those cultivating between 5 and 10 acres scored 2; those cultivating between 11 and 15 acres scored 3; those cultivating 16–20 acres scored 4, and households cultivating >20 acres scored 5.

The second indicator of natural capital was the type of land tenure system under which the household is operating. The type of land tenure and level of security it provides may have serious implications for the management of agricultural soils, and could indirectly affect crop productivity and environmental sustainability, consequently influencing household vulnerability (Deininger and Jin, 2006; Besley, 1995). Three different tenure arrangements were identified in the study communities. These were "land inherited", "land purchased" and "land rented" by the households. A score of 1 was given to households who rented their farm lands; 2 for households who purchased their farm lands; and 3 for those who inherited their farm lands. Households that inherited their farm lands were given the highest score because it is assumed that they will have the most secure land tenure (Toulmin and Quan, 2000).

5.2.4 Financial capital

Financial capital assets such as savings and remittances play a crucial role in cushioning households against drought-related food insecurity. Eliciting information on financial assets was very problematic because of a lack of records of sales and memory lapses. Livestock were considered to offer readily available cash in times of crop failure due to erratic rainfall patterns in the study communities (see Hesselberg and Yaro, 2006). Households without poultry or livestock were scored 1 whilst those with poultry or livestock were scored 2.

Financial assets were also assessed by examining the remittances received by the household from family members or friends over the past 12 months. In rural agriculture-dependent communities, remittances from family and friends play a crucial role in helping peasants to cope with the livelihood impacts resulting from climate variability. Households that received remittances in the last 12 months were scored 2 and those that did not receive any remittances were scored 1. Access to credit is one of the major challenges confronting rural peasants (Deressa *et al.*, 2009). Access to credit may also influence adaptation to climate change including access to inputs such as improved cultivars of crops (Butt *et al.*, 2006). Hence, it is assumed that households that have no access to credit will be more vulnerable and were scored 1 whilst those with access to credit were given a score of 2.

Table 5.1: Indicators of household livelihood vulnerability index collected through a household survey across six communities in Ghana

Component	Indicators	Questions posed during data collection to obtain information on this indicator	Challenges and solutions with collecting this data as experienced in the field
Social capital	No. of associations households belong to	Do you belong to any social groups? Could you please list them in the spaces provided?	Once the definition of a group (and association) was made clear to respondents, there was very little confusion.
	Access to extension advice	Do you have access to extension advice? How many times within the last 12 months.	This was a fairly straightforward question.
	Access to climate information	Do you have access to climate information?	Once respondents understood what constituted climate information, this question posed no challenges.
Human capital	Educational level	Could you please state the highest education attained?	No difficulties were encountered by respondents on this question.
	Health status	Have any member of this household been ill in the 12 months? Did the person visit the hospital as an out-patient or hospitalise as an in-patient?	Difficulties related to what constituted illness. Once this was explained as illness needing hospital treatment, there were no problems.
Natural capital	Farm holding size	Could you please state the size of farm holding in acres?	Problems related to landholding but this was resolved as respondents were made to understand that this question related to farm holding under cultivation.
	Tenure system	By what arrangements do you have access to your farm land for farming activities?	Problems related to few farmers who had more than one tenure arrangements. In such cases, the major tenure under which the household cultivates their crops was considered.
Financial capital	Access to credit	Do you have access to credit for your agricultural activities?	Once respondents understood what constituted credit, this question posed no challenges.
	Ownership of livestock	Do you have livestock or poultry? List the types and numbers of livestock and/or poultry.	This was straightforward question which posed no difficulties.
	Remittances received	Have you received remittances from family or friends in the last one year?	There were difficulties relating to memory lapses. Hence, the duration was specified to be the last 12 months to help households recollect.
Physical capital	Irrigation facilities	Do you have access to irrigation facilities for dry season farming?	This was a straightforward question and posed no problem.
	Possession of television & radio	Could you please list all communication gadgets that you have? These include TV, radios, mobile phone etc.	These were clearly identifiable things so there was less confusion relating to this question.
Livelihood diversification	Livelihood diversity index	What are your main livelihood activities? Could you rank these in terms of their contributions to household income?	Problem related to what could be classified as a livelihood. Efforts were made to explain to respondents that this includes all activities they undertake to make a living.

5.2.5 Physical capital

Physical capital assets that were assessed included the presence of irrigation facilities and ownership of radios, television or mobile phones by a household. Irrigation facilities are crucial for rain-fed agriculture-dependent communities, as these facilities help farmers to practise dry season farming. It is hypothesised that households with irrigation facilities will be less vulnerable to changing rainfall patterns. Hence, households without irrigation facilities were scored 1, whilst those with these facilities were scored 2. The presence of radios, television or mobile phone in a rural household can be an effective tool for communication and accessing information on changing weather patterns (Naab and Koranteng, 2012). Here, households with any of these three assets were scored 2, and those without any scored 1. Physical assets such as road networks and the availability of markets and health facilities may enhance the adaptive capacity of a household (Zhang *et al.*, 2007). For instance, the development of rural infrastructure could encourage the development of non-farm enterprises (Gbetibouo *et al.*, 2010). Good road networks will mean that farm produce is transported to the market in good time and sold in order to obtain financial resources that can be used to purchase food items to reduce the vulnerability of households to drought-related food insecurity (Zhang *et al.*, 2007). These assets were not included in the vulnerability computation because, during fieldwork, it was discovered that these assets did not significantly differ amongst various households either in the resilient or vulnerable communities.

5.2.6 Livelihood diversification

In addition to exploring the five capital assets, this thesis also examined whether households in resilient and vulnerable communities diversified their livelihood activities. Diversification has been reported as one of the main strategies for reducing household vulnerability to the impacts of climate variability (Ellis, 1998; Datta and Singh, 2011; Barrett *et al.*, 2001). Therefore, the number of livelihood activities that a household was engaged in was assessed. It is assumed that households with more diversified livelihood sources may be less vulnerable to the impacts of climate change compared to households that depend only on agriculture. The livelihood approach argues that agriculture-dependent households may be able to reduce their overall vulnerability to climate variability by diversifying the strategies pursued within their livelihood portfolios or specialising to take advantage of a niche (Bebbington, 1999; Ellis, 1998; Fraser *et al.*, 2005). Hence, the livelihood vulnerability index is estimated to be directly proportional to the number of livelihood activities in which a household engages. A score of 1 was given to households that had only one livelihood activity, 2 for households having two livelihood activities, 3 for those with three livelihood activities, 4 for those with four livelihood activities, and households with >4 livelihood activities scored 5. Having explained how the indicators of capital assets were characterised and selected, what follows is an explanation of how these indicators were standardised and weighted.

5.2.7 Standardization and weighting of selected indicators

To ensure comparability in the construction of the household livelihood vulnerability index (HLVI), all indicators were standardized following the UNDP (2007) procedure of standardising indicators for life expectancy index (equation 5.1). This ensures that all indicators were normalised to have a relative position between 0 and 1 (see Vincent, 2004; Gbetibouo *et al.*, 2010; Hahn *et al.*, 2009).

$$\text{Index value(standardized value)} = \frac{\text{Actual value} - \text{Minimum value}}{\text{Maximum value} - \text{Minimum value}} \tag{5.1}$$

Having standardised the indicators, it was then necessary to elicit appropriate weights to them. An unequal weighting system, based on relative importance attached to each indicator by local households, extension officers, key informants and experts was used because it was deemed necessary to include the views of both local households and experts in the assessment. Hence, a five-point Likert scale was used where households, extension officers, key informants, and experts were asked to rank the five most important indicators that they considered to influence household vulnerability. The number of times a particular indicator was cited was used to generate the weighting system. The following weights were assigned: 14% to social capital, 11% to human capital, 9% to natural capital, 27% to financial capital, 10% to physical capital and 29% to livelihood diversification (Table 5.2). The household livelihood vulnerability index for a household was then calculated using the following model (equation 5.2) (Vincent, 2004).

$$HLVI = (Ssvi * Wi) + (Hsvi * Wii) + (Nsvi * Wiii) + (Fsvi * Wiv) + (Psvi * Wv) + (Lsvi * Wvi) \quad (5.2)$$

Where, HLVI = household livelihood vulnerability index, Ssvi = standardized value of social capital asset sub-index, Hsvi = standardized value of human capital asset sub-index, Nsvi = standardized value of natural capital asset sub-index, Fsvi = standardized value of financial capital asset sub-index, Psvi = standardized value of physical capital asset sub-index, and Lsvi = standardized value of livelihood diversification sub-index. The Wi terms refer to the weighting that was applied to each standardized value: Wi = 0.14, Wii = 0.11, Wiii = 0.09, Wiv = 0.27, Wv = 0.10, and Wvi = 0.29 (see Table 5.2). The inverse of the value for the indicators was estimated to ensure that high values always indicated high vulnerability. The line of reasoning here is that low vulnerability indices reflect lower vulnerability of a particular household or community and therefore, by taking the inverse of the standardized value, the resultant value will reflect the extent of the vulnerability of the household or community. This has important implications in conveying the findings of this study to policy makers as it is easier to communicate that high vulnerability index scores denote high vulnerability.

The results presented in this chapter are limited by the fact that using current proxy indicators based on the existing vulnerability of households poses a problem when considering vulnerability to climate variability in the future since these indicators are dynamic (Eakin and Bojorquez-Tapia, 2008; Vincent, 2007). The household livelihood vulnerability index provides a snapshot in time of the vulnerability of a particular household and therefore fails to capture its changes over time and space. Nevertheless, it helps in the identification of vulnerable communities and households at the current time, as well as guiding appropriate adaptation pathways (Adger and Kelly, 1999; Abson *et al.*, 2012). The use of the SLA as analytical framework presented some challenges in relation to temporal dimensions, power dynamics and multiple scales. These concerns were addressed through the use of participatory methods and the exploration of vulnerability across different scales. The difficulties encountered in the use of participatory methods in this thesis are outlined in Chapter 3.

Table 5.2: Weighting system based on local farmers, key informants and experts perceived relative importance of various indicators

Component	Indicator	Times cited as most important	Relative Importance	Weighting (indicators %)	Rank	Weighting (components %)
Social capital	Access to climate information	11	3.86	4.00	9	14.00
	Membership of social groupings	23	8.07	8.00	6	
	Availability of extension service	6	2.11	2.00	11	
Human capital	Educational level of the household	26	9.12	9.00	4	11.00
	Health of the household	5	1.75	2.00	12	
Natural capital	Type of land tenure system	7	2.46	2.00	10	9.00
	Size of farm holding	19	6.67	7.00	8	
Financial capital	Households receiving remittances	24	8.42	8.00	5	27.00
	Ownership of livestock/poultry	21	7.37	7.00	7	
	Access to credit facility	33	11.93	12.00	2	
Physical capital	Access to irrigation facilities	28	9.82	10.00	3	10.00
	Ownership of radios, televison and mobile phones	0	0.00	0.00	13	
Livelihood diversification	Alternative livelihood options	82	28.77	29.00	1	29.00
(N= 270 households, 9 key informants[13], 3 extension officers, 3 experts)		285	100.00	100.00		100.00

[13] Key informants included persons who know something special about such villages including opinion leaders such as chiefs, assemblyman, village teachers and youth leaders who are decision makers in these communities.

5.3 Results

The results of the vulnerability analysis are presented to explore the various factors that characterise resilient and vulnerable communities and households. Section 5.3.1 explores the differences in overall vulnerability between the communities studied, using the livelihood vulnerability index that was constructed based on the information collected in Section 5.2. Section 5.3.2 explores how two key factors, gender of the household head and wealth, affect mean vulnerability. Section 5.3.3 identifies various vulnerability clusters and characterises the households within these clusters. Finally, the chapter uses statistical methods to identify "outlier households" to explain the nature of vulnerability at household level (Section 5.3.4).

5.3.1 Mean vulnerability of the farming communities

The results of the overall vulnerability of the study communities are presented in Figure 5.1. The vulnerability differs significantly amongst the various communities ($p < 0.05$). Within the resilient region, Aframso showed the greatest vulnerability (0.524) with Babaso demonstrating the lowest vulnerability score (0.387). Nyamebekyere recorded a vulnerability of 0.487 (Figure 5.1).

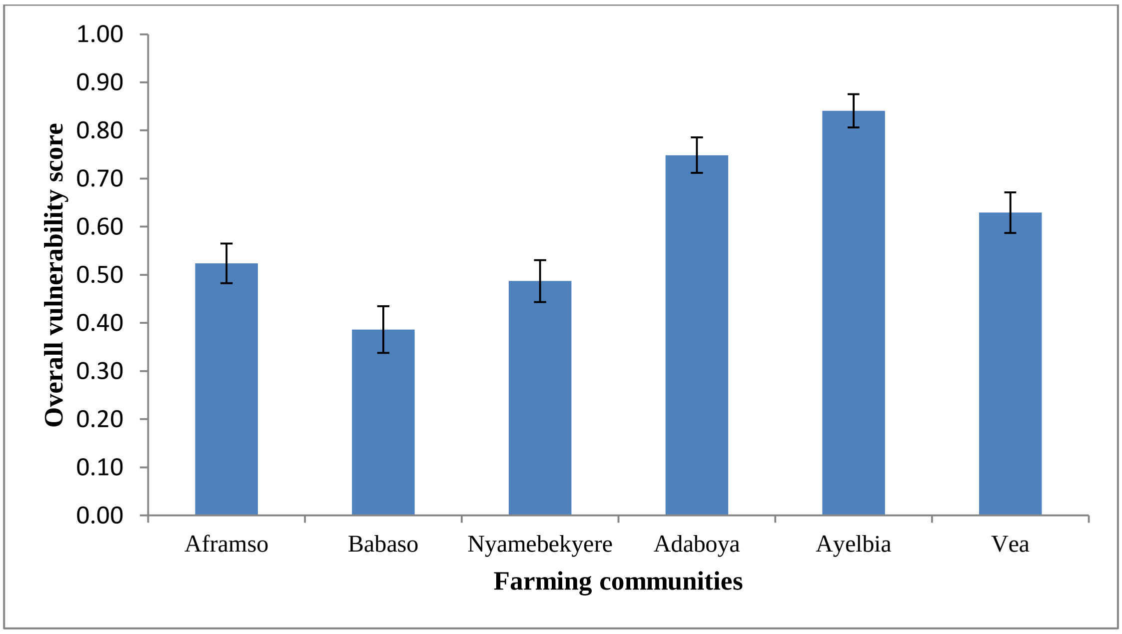

Figure 5.1: Mean vulnerability of the study communities[14]

[14] Aframso, Babaso and Nyamebekyere represent the "resilient" communities while Adaboya, Ayelbia and Vea are the "vulnerable" communities.

Within the vulnerable region, Vea recorded the lowest mean vulnerability of 0.629 with Ayelbia showing the greatest mean vulnerability of 0.841 whilst Adaboya recorded mean vulnerability of 0.749. These results suggest that Babaso (in the resilient region) and Vea (in the vulnerable region) showed the lowest vulnerability in their respective study regions, with Ayelbia being the most vulnerable community amongst the 6 study communities (Figure 5.1).

Figure 5.2 shows the major components contributing to vulnerability for a particular community. Figure 5.2 suggests that a lack of financial capital is the biggest contributor to overall vulnerability in all six study communities. Regardless of the context (whether a household is located in a resilient or vulnerable community); low financial capital pulls up the vulnerability index, increasing vulnerability.

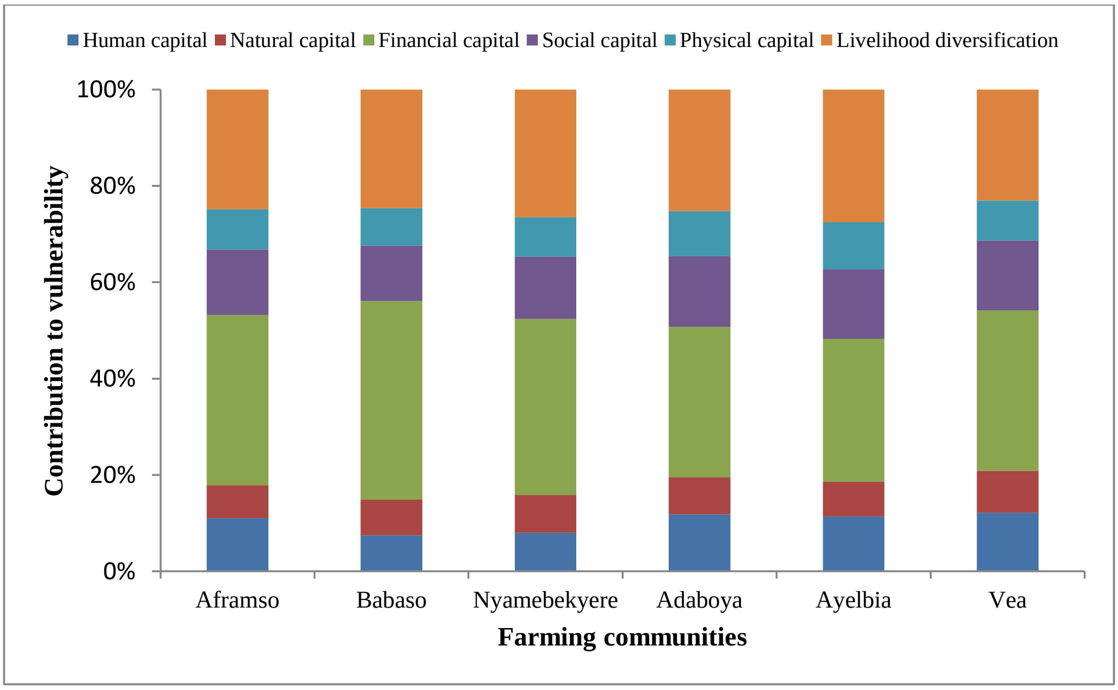

Figure 5.2: Components contributing to vulnerability in the study communities

Access to social capital was greatest in Babaso compared with the other study communities within the resilient region. Vea demonstrated the lowest mean vulnerability among the vulnerable communities for all vulnerability components. Qualitative interview analysis shows that the households at Vea have relatively more diverse livelihood opportunities compared with the other two communities – Adaboya and Ayelbia – in the vulnerable region. For instance, most of the young men at Vea were involved in sand mining that serves as a viable source of income, at least, during the dry season. Another important factor that makes Vea less vulnerable is that there is a very large irrigation dam in the area, which allows farmers to grow vegetables during the dry season. The next section explores how the gender of the household head and wealth influence vulnerability to climate variability.

5.3.2 Gender and wealth analysis

Figure 5.3 presents the mean vulnerability of male-headed and female-headed households in the study communities. Female-headed households demonstrated greater mean vulnerability than their male counterparts in all the farming communities. The result of vulnerability scores based on the different wealth groups also shows that generally, poor households recorded greater mean vulnerability than rich households (Figure 5.3). Poor households were more vulnerable because they tend to have low access to capital assets.

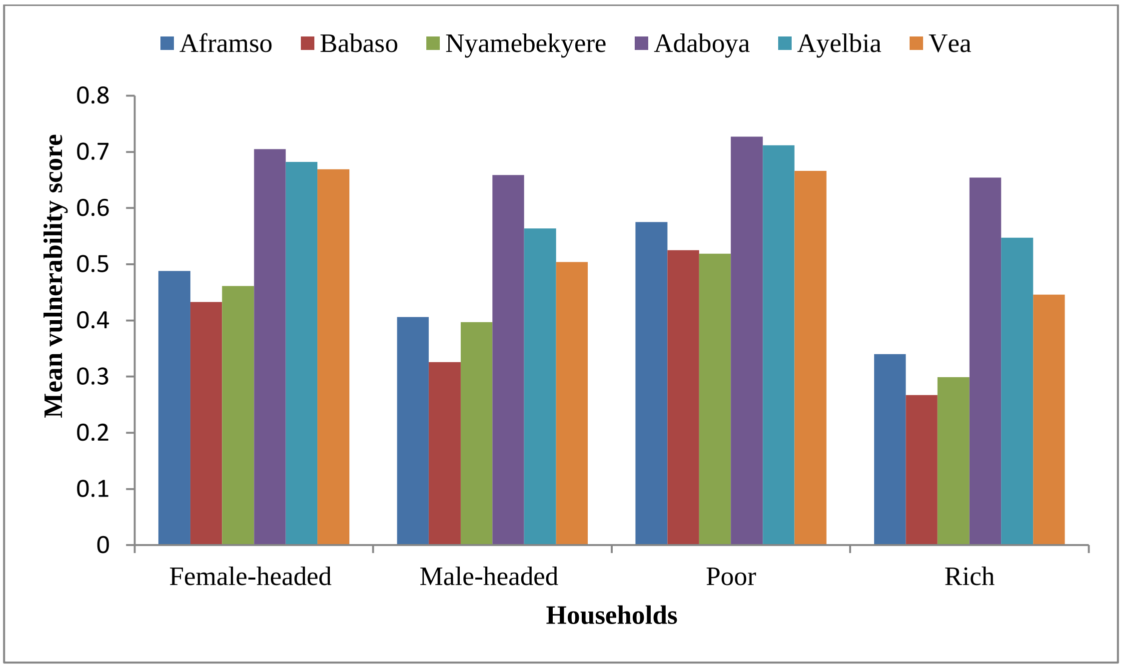

Figure 5.3: Mean vulnerability score based on gender and 'perceived' wealth

Quantitative results show that most of the households in both the resilient and vulnerable communities were characterised by low educational levels (Table 5.3). Nevertheless, the result further suggests that the households in the resilient communities were slightly better-off in terms of educational attainment. For instance, Table 5.3 shows that about 78% of all the households sampled within the vulnerable communities were headed by farmers without any formal education compared with about 47% in the resilient communities. Poor educational standards are characteristic of most farming households in Ghana, where agriculture, including both crop production and livestock rearing, is mostly perceived to be a profession for 'illiterates' and school drop-outs.

Table 5.3: Percentage of respondents by years of education in study communities

Years in Education	Resilient communities			Vulnerable communities		
	Aframso	Babaso	Nyamebekyere	Adaboya	Ayelbia	Vea
0 (None)	51.12	40.00	48.89	82.23	77.78	73.34
6 (Primary)	17.78	15.57	24.44	13.33	15.56	8.89
JSS/Middle	24.44	35.55	20.00	4.44	2.22	13.33
Secondary	4.44	8.88	6.67	0.00	4.44	2.22
Tertiary	2.22	0.00	0.00	0.00	0.00	2.22
Total	100.00	100.00	100.00	100.00	100.00	100.00

5.3.3 Vulnerability cluster analysis at the household level

Despite significant socioeconomic differences across the six study communities; the k-means cluster analysis at the household level shows that there are three major clusters of households belonging to *low, medium and high* vulnerability clusters (Figure 5.4). Indeed, households within a particular vulnerability cluster share similar characteristics in terms of their accessibility to livelihood assets and the livelihood activities pursued. The means of the various vulnerability clusters were significantly different ($p < 0.05$). Figure 5.4 shows the distribution of households according to vulnerability clusters within the various study communities. It shows that Babaso (which demonstrated the lowest average vulnerability) recorded the highest percent of households within the low vulnerability cluster (49%) with only 9% being within the high vulnerability cluster. Further, Figure 5.4 shows that amongst the vulnerable communities, Vea which showed the lowest vulnerability also recorded 9% and 69% of households in the low and high vulnerability clusters respectively. This compares with Ayelbia – the most vulnerable amongst all the study communities – which recorded 2% and 84% of households within the low and high vulnerability clusters respectively (see Figure 5.4).

Quantitative analysis shows that a small proportion of households (including 35% and 5% in the resilient and vulnerable communities respectively) that tend to engage in a number of livelihood activities outside of agriculture were found to belong to the 'low vulnerability' cluster. Households belonging to this cluster had diversified livelihoods including other non-farm jobs such as petty trading and fishing, and also tended to have secure land tenure with relatively large farm holdings (e.g. Cases 4, 5 and 7 in Table 5.4). Hence, these could be described as multi-activity households in which the household pursues more than one livelihood activity. Mostly, such households have a principal livelihood activity, with a number of complementary livelihood strategies. Households in this cluster also tend to be highly socially connected with some having political power in terms of decision making, because of a leadership role as e.g. chief, assemblyman, chief farmer and other opinion leaders (e.g. Cases 5 and 7).

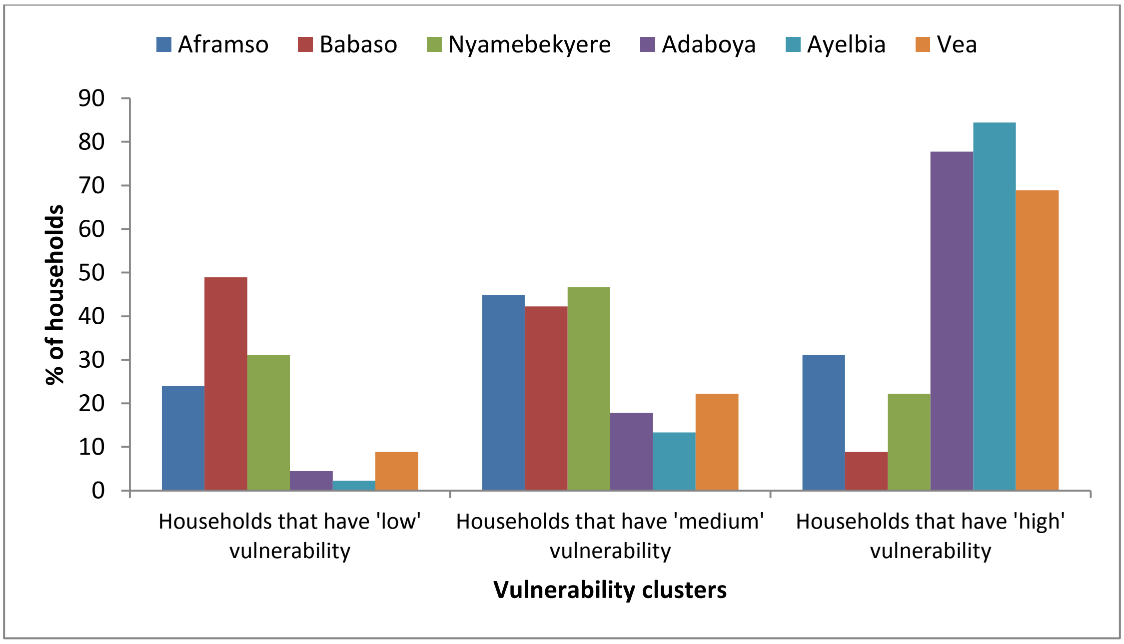

Figure 5.4: Proportion of households in different vulnerability clusters in study communities

About 21% and 77% of households in the resilient and vulnerable communities respectively belonged to the 'high vulnerability' group (Figure 5.4). This cluster comprises single-activity households whose livelihoods were defined principally by agriculture-based activities. They tend to depend solely on crop farming as the principal livelihood activity and have limited social capital in the communities (e.g. Cases 2 and 3 in Table 5.4). In addition, households in this cluster tend to have insecure land tenure (e.g. Case 1). In between the low and high vulnerability clusters is a group of households that were classified as 'medium vulnerability'. These included 44% and 18% of the households in the resilient and vulnerable communities respectively (Figure 5.4). These are households that may have crop farming as a principal livelihood activity but also tend to invest in livestock and poultry production which can be sold when things become hard for such households. They may not be in salaried employment like those in the low vulnerability clusters but have access to bonding social networks that become crucial in drought-related famine.

5.3.4 Identifying outlier households at the household levels

Figure 5.4 reveals that there were outlier households within both the resilient and vulnerable communities. The analysis shows that there were certain households that were extremely vulnerable in the 'so-called' resilient communities. The opposite trends were observed in the vulnerable communities, where there were certain households that were relatively resilient. An outlier household is defined as a household that belongs to the resilient community but actually is put into the high vulnerability cluster by the k-cluster analysis or a household that belongs to the vulnerable community but k-cluster analysis puts that household into the low vulnerability category (Figure 5.4).

The qualitative differences between outlier households and typical households within the same community were explored in greater depth. Identifying such households provides useful insights into the problems that lead to households being vulnerable even in relatively resilient communities. Results revealed that outlier households in the vulnerable communities were more resilient because they have alternative sources of income and have secure land tenure with relatively large farm holdings. They were also characterised by extensive social networks and may have access to both bonding and bridging social capital. On the contrary, typical households within the vulnerable communities (and outlier households at the resilient communities) tend to be less socially connected, depend entirely on crop farming and are characterised by limited access to livelihoods capital assets. Oral narratives were used to reconstruct livelihood histories to explore temporal dimensions of vulnerability of outlier households in dryland farming systems to provide insights into how past events have shaped the livelihood activities of such households. Table 5.4 presents case study examples of the oral histories with outlier households in both resilient and vulnerable communities[15]. What is interesting about these outlier households is that they offer useful insights when compared with typical households within the same community. For instance, an outlier household is contrasted with a typical household regarding their responses to the impacts of the 2007 flood that destroyed most farm crops and livestock at Vea. Recounting the flood at the vulnerable communities, a farmer at Vea noted:

> *"The floods destroyed all my crops including millet, sorghum and guinea corn. [Also], my livestock were destroyed. I did not have money to buy foodstuffs from the market. This affected the household food consumption as we had to reduce the number of meals per day"* [Head of a typical household, July, 2011].

In contrast, outlier households within the same community that have alternative livelihood options as demonstrated by Case 4 (see Table 5.4) were less vulnerable to the adverse impacts of the flood. Explaining how his household coped with the flood of 2007 and drought events in the community, Mr Abanah noted:

> *"During drought events my household rely on income from non-farm jobs to buy foodstuffs from the market. I am a teacher and this is a salaried job that is not affected by these events. As a teacher whether there is drought or no drought, I will be fully paid"* [Head of an outlier household, Vea, July, 2011].

Table 5.5 shows the characteristics of outlier and typical households in the study communities and demonstrates how livelihood diversification and access to capital assets can reduce vulnerability to climate variability.

[15] Since oral history narratives intended to provide a historical perspective to temporal changes in livelihood in relation to major climatic events in these communities, careful considerations were given to the selection of households for this in-depth analysis. Hence, heads of household who were old enough to have witnessed major climatic events as highlighted in the climate timelines of these communities were selected. Most of the farmers selected were aged between 40 and 60 years (see Table 5.4). One of the major droughts in these communities occurred in 1983 and therefore it was assumed that farmers aged at least 40 years would have been old enough at the time of the drought to share their experiences. To ensure variety and good representation of the various socioeconomic groups within the communities, considerations were also given to select both male and female-headed households, as well as migrant workers, in these communities. To facilitate the reconstruction of livelihood history, local and national historical events were used to help farmers estimate roughly when major changes in their livelihood might have occurred. This was important because most interviewees experienced difficulties relating their livelihood history to specific dates because of memory lapses.

Table 5.4: Oral history narratives with example case study of outlier vulnerable and resilient households

Case 1- Vulnerable household in a resilient community: Ms Amina, age 55 years, living with five children at Nyamebekyere*

This household, perceived by the local community as a poor household, is headed by Ms Amina. Born in 1956, Ms Amina, a widow, moved from the Bunkprugu Yooyo district to Nyamebekyere in the 1980s because of the good soil and environmental conditions for farming in this village. During this time, her husband also used to work as a watchman to support the family. They used to cultivate about 8 acres of land and harvested about 50 bags of maize. Ms Amina's husband died in 2007 and she does not have any reliable source of income for the household. This household cultivates on the average, 3 acres of land and harvests about 15 bags of maize. As a migrant worker, Ms Amina stressed the difficulties in accessing the most fertile lands for agricultural activities. She indicated that she either rents land and in return gives a bag of maize per acre of land to the land owner after harvesting or she cultivates the land in what is locally termed as '*abanu'* where the land owner gives you land and planting materials and shares the yields equally after harvesting. Without any formal education, Ms Amina has no alternative source of livelihood apart from farming and she only grows crops. She has no livestock or poultry. To supplement her income, she sometimes works in other people's farms to earn extra income, which means less time on her own farm. She indicated that she has no money to buy fertilizers to improve soil fertility and hence has to rely solely on animal droppings to enrich the soil. Ms Amina does not belong to any farmers associations in the village and does not receive remittances. Ms Amina has observed less rainfall recently compared with when she first moved into this village. According to her the onset of the rains has delayed and the duration of the rains during the farming season is quite uncertain. The household uses different climate adaptation options including changing timing of planting and planting different crops to cope with climate variability. Explaining some of the coping strategies, Ms Amina said: "*Sometimes I work on other farmer's farm in exchange for food".* In terms of barriers to climate adaptation, the household highlighted lack of funds, the high cost of improved varieties of crops and land tenure insecurity. Ms Amina said: *"It is very difficult for farmers to obtain credit for farming operations in this community. I rely on my limited personal resources to plough the land. I provide all the farm labour myself."*

Case 2 - Vulnerable household in a resilient community: Mr Kwame Musah, aged 60 years, living with wife and seven children at Babaso*

Mr Musah moved to the Babaso community when he was 20 years old with his parents. When Mr Musah moved into this village the rains were plentiful and appropriately timed which allowed them to cultivate maize, yam and groundnut. During this time, the household cultivated about 10 acres of land for maize, groundnut and yam. According to Mr Musah, when they first moved to this village, rainfall was not as erratic as it is now. They could plant their crops without worrying too much about intra-annual rainfall variability. Mr Musah has also perceived increasing temperature patterns compared to when he first moved into this village. Mr Musah indicated that he is now old and not able to cultivate a large area of land. Apart from that there are issues with land tenure. Since the year 2001, Mr Musah has been cultivating less than 5 acres of maize and beans. Apart from farming the household has no other alternative source of livelihood. The household has no livestock but keeps small poultry (less than 10 fowls) which are sold in difficult times. He has no formal education and occasionally works as a labourer in other people's farms to earn extra income to support the household. His wife, Ms Saliatu has no formal education and helps her husband in their farming activity. Neither Mr Musah nor his wife belongs to any association in the village or outside the village. Though he has a radio for listening to the news, he has no television set, no spraying machine and no mobile phone. The household does not receive any remittances from relatives or friends and therefore relies solely on crop farming. The major difficulties confronting this household are lack of secure land tenure and credit for farming activities.

Case 3 - Vulnerable household in a resilient community: Ms Adwoa Owusuwaa, aged 58, living five children at Aframso*

Born in Aframso, when Ms Owusuwaa started farming, the rains were quite predictable and farmers could appropriately time this for planting their crops. She used to cultivate maize and did not have to rely so much on fertilizers for higher yields as the soil and the rainfall were reliable. According to her, since the late 1980s, the rainfall pattern has become less reliable. The drought of 1983 destroyed her maize farm and other cash crops including cocoa. She and her husband started growing other crops such as groundnut in the early 1990s. In response to the increasingly erratic rainfall patterns in the community, in the 1990s this household began growing cassava that is drought tolerant. During this period, the household used to invest part of the money from their crop farming into livestock and poultry. Her husband used to work as a tailor which earned the family extra income. Ms Owusuwaa lost her husband in 2000 and things have become quite difficult since then. Currently, the household cultivates only 3 acres of land for maize and rice and sometimes has to rely on friends and family to obtain food. Without formal education, Ms Owusuwaa has no alternative sources of livelihood apart from farming. Ms Owusuwaa put this bluntly as *"I have no alternative sources of livelihood and rely entirely on crop farming to feed my family. This means that anytime the rains fail me then my household is in serious trouble in terms of food for the family. This problem is compounded by the fact that I receive no remittance from anywhere."* Currently, this household has no livestock or poultry. The household has no bicycle or spraying machine. Also, they have no radio, mobile phone, or television in the house. Members of the household rely solely on food from their farm. Neither Ms Owusuwaa nor any of her children belong to any association in the village. Lack of funds, limited access to and high cost of improved varieties of crops, and lack of farm implements, are some of the main barriers confronting the implementation of appropriate climate adaptation by this household.

Case 4 - Resilient household in a vulnerable community: Mr. Abanah, aged 43, living with wife and four children at Vea*

Born and growing up at this village, the head of this household, Mr Abanah is a degree holder. Mr Abanah has been a professional teacher since 1993 and is the head teacher of the local primary school. This household is considered by the local community to be rich. Apart from farming, the household also keeps livestock and poultry. Mr Abanah is also the Assemblyman for the Vea electoral area and one of the opinion leaders upon whom most of the people in this community rely for decision making concerning this community. He receives a salary from his teaching profession and allowances when he attends meeting at the assembly. As a strategy, this household invests part of their salary in livestock production by buying livestock from other farmers in the village and surrounding communities during the dry seasons when the price of livestock are generally cheap as farmers need to sell to get money to buy foodstuffs to feed their families. Mr Abanah indicated that his household sells their livestock when the prices are good. The household has two acres of irrigated land around the Vea irrigation dam and this allows them to cultivate tomatoes during the dry season. The household also owns a motor bicycle, radio, and mobile phone, which they use to listen to and access information. Mr Abanah inherited his farm land from his father and therefore has secure land tenure. The household grows late and early millet, guinea corn, beans and sorghum. Mr Abanah is a member of the Ghana National Association of Teachers. Since the 1990s this household has changed their cropping patterns and grows improved varieties of crops in response to climate variability. Additionally, the household has changed its timing of planting since the late 1990s, and grows different crops at the same time. Importantly, the household is engaging in more non-farm jobs. Lack of institutional support through extension services, limited access to improved varieties of crops and lack of farm implements are some of the major barriers to climate adaptation highlighted by this household.

Case 5 - Resilient household in a resilient community: Mr. Odum, aged 52 living with wife and five children at Nyamebekyere*

Headed by Mr Odum, this household lives in a three bedroom aluminium zinc roofed house and is perceived by the local community as rich. Born in 1957 in Mampong, Mr Odum moved to Nyamebekyere in 1971. Mr Odum claimed that the rainfall patterns have changed. "*When I moved into this village, the rains used to start a bit early in February for planting to be done. But now the rains do not come until late March."* Apart from farming, Mr Odum keeps livestock and poultry. He has 30 sheep and 25 goats with a number of poultry. Mr Odum has a Middle School Leaving Certificate. He also works as a lands revenue collector which brings him extra income. He earns 15% as commission of the total revenue he collects for the land administrator in Kumasi. His wife, Ms Mantey, who has primary education, is also a petty trader who buys foodstuffs from farmers at the Nyamebekyere village and sells them at the Ejura market. The household is able to cultivate 15 acres of land and harvests, on average, 100 bags of maize, and 25 bags of beans per annum. Mr Odum also has three older children who work in different parts of Ghana (in Kumasi, Dunkwa and Accra). Mr Odum claims his household regularly receives remittances from his older sons who are businessmen. One of his sons is a head teacher at Dunkwa, and another is businessman at Ejura. Mr Odum said: "*My sons send us money regularly and this is used to help with our farming activities including ploughing, purchasing fertilizers and other farm inputs. This makes us less vulnerable to drought because we are able to plant on time to avoid the drought during the critical period of maize."* Mr Odum continued: *"Because of this we are always one of the first households to harvest in this village and this gives us premium prices for our cereals including maize."* Mr Odum is a member of the Millennium Development Account, which helps farmers with farm inputs such as fertilizers and seeds. Mr Odum and his wife are members of the local Pentecostal church, which serves as informal network for information sharing. In response to climate variability, Mr Odum claimed to have changed his cropping patterns. *"I now grow the improved varieties of maize such as obaatanpa, dobidi etc that are early maturing."* The major challenges confronting this household in terms of climate adaptation include the lack of and/or high cost of farm inputs, lack of reliable climate adaptation information especially regarding the onset and duration of the rainfall, and lack of institutional support. Elaborating on the barriers to climate adaptation, Mr Odum stated: *"We are not able to receive accurate and reliable information from the weather people in terms of the distribution of the rainfall and this makes it very difficult for farmers to plan their farming activities."* The household owns a television, radio, and a mobile phone, which they use to communicate and access information on weather forecast.

Case 6 - Resilient household in a vulnerable community: Mr. Ataana, age 54, living with wife and six children at Adaboya*

This household is considered rich by the local community and is headed by Mr Ataana. Born and growing up in this village Mr Ataana grows millet, groundnut, sorghum and beans. In 1990, Mr Ataana and his wife started keeping livestock to supplement their income from farming. During this time, he used to work as a watchman at Bolgatanga, which brought some extra income to the household. The household invested part of the money from this watchman job into livestock and fowl production. In 1990, they started with 3 sheep and 2 goats but by the end of 2000, they had about 35 sheep and 15 goats. Mr Ataana holds a Middle School Leaving Certificate. His wife, Ms Mamunatu, with primary education, is a petty trader who sells at the Bolgatanga market. Ms Mamunatu also picks and sells shea nuts whilst Mr Ataana is engaged in basket and hat weaving, all of which bring in extra income to support this household. The household on the average cultivates 4 acres of land for millet, sorghum and beans. Mr Ataana is a member of the *Alawaba Farming Group* which is supported by the UNDP through the provision of donkeys and donkey carts. Mr Ataana has also benefited from the Africa 2020 Network which provided him with ruminants and guinea fowls. In addition, the household receives remittances from their working children in Bolgatanga and Sunyani. Their son in Bolgatanga is a driver and the one in the Sunyani is a teacher and also sells farm inputs. The household has a radio and mobile phones. In addition, they have a motor bicycle which facilitates their movements in and out of this village. Mr Ataana was assemblyman from 2004 to 2010, a position for which he received sitting allowance.

*Case 7 - Resilient household in a vulnerable community, Mr Gambila**, age 40, living with wife and two children at Ayelbia*

This household that is considered rich by the local community is headed by Mr Gambila. Born and growing up in this village, Mr Gambila completed Senior Secondary school at Bongo. The head of the household inherited the farm land from his parents who were farmers themselves. When he was growing up in this village the rainfall was less erratic. The household cultivates about 4 acres of land for different crops such as millet, sorghum, maize and groundnut. This household keeps livestock and has 8 sheep, 6 goats and about 30 fowls. Apart from farming, Mr. Gambila is employed as a *'pupil teacher'* at the local primary school, a position that brings him extra income. He has been the Assemblyman for this community since 2006 and a member of the village development community, a position which gives him access to other political leaders in the district and beyond. His wife, Ms Azubila is a petty trader who buys millet and other foodstuffs and sells them at the Bolgatanga central market. The household has a radio, motor bicycle, and two mobile phones. In terms of adaptation, this household uses crop diversification and diversification of livelihood activities to cope with drought in this community. The main challenges they confront regarding the implementation of adaptation strategies include a lack of adequate funds to purchase fertilizers, hire tractors and buy other farm inputs.

*Real names of farmers have not been used

Table 5.5: Key characteristics of the outlier and typical households in study communities

Household	Within resilient communities		Within vulnerable communities	
	Outlier vulnerable households	**Typical households**	**Outlier resilient households**	**Typical households**
Human assets	Such households do not have any formal education with relatively large household sizes.	Most households have at least primary education. Can be male or female headed households.	Relatively educated households (most with at least 6 years of education).	Members of such households have no formal education.
Principal livelihood activities	Crop production on a subsistence basis. May not have livestock or poultry and therefore depend solely on crop farming.	Have diversified their livelihood sources into non-farm income jobs. Mostly involved in monoculture commercial crop production systems.	Households have at least one member who is in permanent employment or commercial business. These non-farm income jobs are less negatively impacted by climate variability.	Depend mainly on crop farming to feed the household. Crops grown include sorghum, millet and beans. No form of non-farm jobs for most households.
Natural assets	Majority of households tend to be migrant farmers who are landless and have insecure tenure. Hence, have small farm holding.	Have access to land and tenure security. Have relatively larger farm holding but tend to engage in monoculture commercial cropping patterns because of mechanization.	Households have access to land and secure tenure. Some households have access to irrigation facilities and are able to invest in improved varieties of crops.	Have relatively small farm holdings, with poor soil due to continuous cultivation of same land without the addition of suitable soil amendments. Female-headed households have no tenure security.
Poverty levels	Poverty levels are relatively high compared with typical households in such communities. Have difficulties in accessing credit and do not receive remittances.	Poverty is moderate because of access to non-farm income. May receive regular remittances from families and friends working in the cities.	Received income from non-farm jobs which gives such households some form of financial security.	Extremely poor without access to credit. Unable to sell farm produce as a source of support because of small farm holding. Rely on external support during climate-related crisis.
Social assets	May belong to at most one social grouping. Have no real political power within such community. Social identity includes crop producers.	Highly connected to wide range of social networks. Some households may have access to both bonding and bridging social capital.	Have access to bridging social capital in terms of membership of recognised groups. Some may have political power in the village because of their social status.	Generally, households do not belong to any recognised social grouping. Have no political power in terms of decision making in the village. Mainly crop producers with few livestock keepers.

5.4 Discussion

Results show that rural households with access to capital assets (financial, human, natural, physical, and social) are less vulnerable to the negative impacts of drought (Table 5.5). The findings suggest that diversification of livelihood activities into non-farm income jobs is crucial for coping and adapting to drought in rain-fed agricultural systems. Also, access to land and power relations within the study communities are critical in influencing the vulnerability of households to drought. These points are expanded on in the following sections, and their implications for drought vulnerability and food security are explored.

5.4.1 Gender and climate vulnerability

The analysis shows that female-headed households without any reliable sources of income in all the study communities were more vulnerable than male-headed households (see Cases 1 and 3; Figure 5.3). For instance, outlier households Case 1 and Case 5 provide insightful characteristics worth noting. Outlier case 1 shows that the household has no reliable sources of income and that they depend solely on crop farming. The head of the household, Ms Amina claimed that she earned about 10 Ghana cedi (US$6.67) per day by working as a labourer on other farmers' farms (see Case 1). This amount is able to take care of the household for less than 4 days and according to her, she will have to wait for the opportunity to be employed by another farmer. This contrasts sharply with Case 5 in the same community (i.e. Nyamebekyere), where the head of the household, Mr Odum, claimed that he has other non-farm income sources and receives remittances from their children. By receiving support from their sons, this household is able to plan their planting and other farming activities that are very crucial in these communities. With rainfall becoming more erratic in SSA (Boko *et al.*, 2007), if a farmer misses the onset of the rains, then that can ultimately affect crop productivity.

Vulnerability of female-headed households may be attributable to the lack of equal opportunities in terms of access to farm land, especially for those in the vulnerable communities. During FGDs, female-headed households claimed to generally have limited access to farm lands. Gender inequalities in access to land in many parts of Africa are well-documented (Place, 2009; Quan *et al.*, 2004; Hilhorst, 2000). In Ghana and especially in the vulnerable communities, farm lands are more easily accessible to males than females. Women have weak tenure rights compared to their male counterparts (Whitehead and Tsikata, 2003). There are complex land tenure systems that govern land distribution and this has often resulted in cultural discrimination against women and unequal access to farm lands by female farmers (Yaro, 2010; Bugri, 2008). As already noted in Chapter 3, land inheritance in the vulnerable communities is through the male heir, and female right of usufruct is not recognised under customary law (Yaro, 2010). Indeed, complex tenure systems in the study communities serve as a barrier to climate adaptation that could compound the vulnerability of female-headed households (how lack of land tenure security accentuates the vulnerability of female farmers is flagged up in Section 7.5).

Another possible explanation for higher vulnerability of female-headed households could be linked to social differentiation and unequal power relations between women and men. Gender inequalities have often resulted in differential access to capital assets and opportunities for livelihood diversification (Denton, 2002). This is especially important in dryland farming systems in SSA where women have limited access and control over physical resources and assets such as radios, irrigation facilities and transportation systems that could enhance their capacity to adapt to climate variability (Naab and Koranteng, 2012). These findings reaffirm previous studies (e.g. Kakota *et al.*, 2011; Glazerbrook, 2011), and contribute additional evidence that suggests that landless female-headed households without any reliable non-farm income jobs are more vulnerable than male-headed households. This has implications for policymakers and development partners in enhancing drought preparedness of different households in such communities and implies that a targeted approach is needed to assist female-headed households.

5.4.2 Vulnerability of different wealth groups

The wealth of particular households could greatly influence their vulnerability. For instance, Figure 5.3 shows that households that were perceived to be poor by the local community recorded higher average vulnerability scores compared with relatively richer households within the same community that may be experiencing a similar level of climate exposure (e.g. compare outlier Cases 5 and 1). Indeed, several writers have documented the role of wealth in enhancing the adaptive capacity of rural poor households (Moser, 1998; Sen, 1999; Moser and Satterthwaite, 2008). For instance, Moser and Satterthwaite (2008) argued that the asset portfolio of the household is crucial in determining its capacity to reduce the impacts of climate change and variability. Generally, at the household level, poverty may greatly influence the extent of vulnerability because poor households have limited asset portfolios that can be used to reduce the impacts of climate change and variability on their livelihoods (Adger and Kelly, 1999). Results here support Sen's (1999) argument that poverty constrains the capability of poor households to cope with the impacts of climate variability.

5.4.3 Access to human capital assets and vulnerability

The analysis shows that vulnerable households were characterised by low education. Outlier households in the resilient communities and typical households in the vulnerable communities which demonstrated the greatest vulnerability to drought were defined by low educational levels (e.g. Case 1 and Case 3; Table 5.5). Increased literacy can increase the capacity of the household to access climate information, which can subsequently enhance the adaptive capacity of the household to buffer against negative impacts induced by climate change and variability (Leichenko and O'Brien, 2002). Education can also have a positive impact on overall farm productivity, and this is especially crucial in the context of dryland farming systems in SSA. For instance, Innes (2010) argues that education may change the belief systems of a particular farmer which may be inimical to increased agricultural productivity. Consequently, this may increase the farmer's willingness to accept agricultural innovations and new technologies to cope with current climate variability that are essential for increased farm productivity (e.g. Lin, 1991). Invariably, this helps such households to build their adaptive capacity to cope with future climate change. In this regard, Lin (1991) reported that education can positively impact on the adoption of new agricultural technology. Low educational standards (such as Cases 1 and 2) limit the capacity of a household to increase their potential for non-farm livelihood activities (Paavola, 2008).

5.4.4 Livelihood diversification

Supporting the studies by Ellis (1998) and Barrett *et al.* (2001), this chapter has shown that vulnerable communities were characterised by households with limited options in terms of livelihood diversification. For instance, comparing outlier case study households in Cases 4 and 5 (i.e. resilient households) with Cases 1 and 2 (i.e. vulnerable households) suggests that those households that have diversified their livelihood activities were less vulnerable compared with those that depended solely on agro-based farming activities. By diversifying their livelihood sources and having access to or ownership of a range of different capital assets, resilient households have a broader livelihood portfolio that they can use to reduce their vulnerability to drought (Ellis, 1998; Fraser *et al.*, 2005). Cases 6 and 7 provide further evidence to suggest that the availability of alternative non-farm income jobs is crucial for the survival of rural agriculture-dependent households in the face of climate variability. Building on previous research on livelihood diversification (Sallu *et al.*, 2010; Paavola, 2008; Ellis, 1998; Barrett *et al.*, 2001), these results provide additional evidence to show how rural households in vulnerable communities employ a range of non-farm livelihood activities with different risk attributes as complementary strategies to buffer against the negative impacts of drought on rural livelihoods.

5.4.5 Institutional support and social capital

Another significant feature of outlier households that can shed some insights into the characteristics of vulnerable households is the kind of institutional support and social capital available. Outlier households in the vulnerable communities (see Cases 4 and 7) have greater access to social and political capital compared with typical households within the same communities. In addition, oral history narratives with outlier households in the vulnerable communities revealed that such households have access to bonding social capital through family and ethnic ties, whereas their positions as assemblymen, chiefs, teachers, and other opinion leaders give them access to bridging capital which transcends ethnicity and socioeconomic factors. Also, such households can rely on their informal networks such as the church in times of crisis or drought-related famine. By contrast, outlier households within the resilient communities and 'typical' households in the vulnerable communities have limited access to bonding capital. More so, their lack of access to external ties does not allow them to access bridging capital. In this regard, social networks may directly or indirectly influence household's adaptive capacity to mitigate the effects of climate variability as well as the type of adaptation strategy available to an individual household (Adger, 2003).

Several writers have documented the role of social capital in coping with the adverse impacts associated with environmental (including climate) change in communities (Adger, 2003; Osbahr *et al.*, 2010). For instance, Sallu *et al.* (2010) observed that households in Botswana that were socially connected were able to take advantage of institutional and economic changes and therefore engaged in livelihood activities that were less vulnerable to climate variability.

5.4.6 Interaction between natural capital assets and climate vulnerability

In terms of natural capital and vulnerability, ecological data suggest that the resilient communities were more diverse than the vulnerable communities[16] (see Appendix 3). The analysis further suggests that typical households at Babaso and Nyamebekyere (in the resilient region) which showed the overall lowest mean vulnerability were characterised by a high natural capital base compared with outlier households within these communities (Table 5.5). A similar instance was observed within the vulnerable communities, where outlier households were characterised by high natural capital asset compared with typical households (Table 5.5). This high natural capital needs to be explored in terms of its implication for food security in rural agricultural households in SSA and how this relates to the overall household vulnerability to climate variability. This is because natural capital assets may provide useful economic opportunities to agriculture-dependent households in rural communities. For instance, picking of wild food including nuts, honey, mushrooms and snails as well as hunting for bushmeat such as grass cutter (*Thryonomys swinderianus*) and bushbuck (*Tragelaphus scriptus*) may constitute a significant source of food to reduce vulnerability to drought-induced food insecurity in the study communities, and Ghana more widely (e.g. Pouliot and Treue, 2013; Ahenkan and Boon, 2011).

[16] Out of the 1949 individual plants identified (belonging to 63 different species, 49 genera and 24 families), 1592 individuals (representing 82 %) were recorded in the resilient communities whereas 357 individuals (representing 18 %) were identified in the vulnerable communities. In terms of agro-ecological diversity, the resilient communities (i.e. Nyamebekyere, Aframso and Babaso) were significantly more diverse than the vulnerable communities (i.e. Adaboya, Ayelbia and Vea) ($p < 0.05$). With regard to ecosystem diversity, the resilient communities were also significantly more diverse than the vulnerable communities ($p < 0.05$).

Despite the relatively high natural capital base of such households, they tend to have lower agro-ecological diversity because of the farm management practices pursued (Table 5.5). During ecological surveys, it was discovered that monoculture cropping is not an uncommon farming practice at the resilient communities. Perhaps, this evidence suggests that communities and households with good natural capital resources tend not to farm sustainably, reaping short-term gains potentially at the expense of the long-term. This contributes to our theoretical understanding of how natural capital interacts with farm management. Indeed, this result builds on work by Fraser and Stringer (2009) that suggests that farmers with a good natural capital base sometimes tend to use unsustainable farm management practices.

5.5 Conclusions and policy implications

This chapter builds on a national and regional-level vulnerability assessment (Chapter 4) by developing and applying a livelihood vulnerability index at the community and household levels to characterise the nature of climate vulnerability. This targets an important gap in the literature, improving understanding of the processes and factors that create vulnerability, with a view to guiding the development of effective policies. This chapter has shown that within the same agro-ecological settings, different communities and households may experience differential vulnerability that may be attributed to differences in livelihood characteristics. The analysis also shows that vulnerable communities tend to have households that are characterised by low levels of human, natural, financial, physical and social capital assets.

Further, results identified vulnerable households within the resilient communities as well as more resilient households within vulnerable communities. These novel results suggest that outlier households in vulnerable and resilient communities could offer useful insights into climate vulnerability at the household level. For instance, outlier households in vulnerable communities have an array of alternative livelihood options and tend to be socially connected, enabling them to take advantage of opportunities associated with environmental and economic changes. On the contrary, the results demonstrate that outlier households in the resilient communities tend to be less socially connected, depend entirely on crop farming and are characterised by limited access to livelihood capital assets. Therefore, identifying such outlier households provides valuable insights into the problems that lead to households being vulnerable even in relatively resilient communities.

This chapter also provides innovative methodological steps in relation to livelihood assessment that can be used to characterise adaptive capacity and hence, the vulnerability to drought of a particular farming community. Although it is acknowledged that local-level vulnerability assessment is very resource intensive, the innovative methodological approach outlined in this chapter is reproducible and will improve drought vulnerability assessments in Ghana and more widely. This chapter has provided a more nuanced understanding of how different households could be impacted by climate variability. Building on previous research on livelihood diversification and livelihood capital assets, a clear need has been identified to support rural households through their participation in non-farm livelihood activities to reduce the negative impacts of drought. Findings in this thesis will help to guide a more general discussion of the sorts of livelihoods that enhance adaptive capacity to future climate changes and thus allow households to maintain food security.

The implication of the results is that policy makers need to formulate specific and targeted climate adaptation policies and programmes that foster asset building so as to increase the capacity of vulnerable households to engage in non-farm activities that are less likely to be adversely impacted by climate variability. This should be linked to enhancing livelihood diversification as well as institutional capacity and social capital. Vulnerable households should also be targeted in terms of resource allocations and other interventions aimed at reducing vulnerability to climate variability.

CHAPTER 6

ADAPTATION TO CLIMATE VARIABILITY: AN EMPIRICAL STUDY FROM TWO REGIONS IN GHANA

Summary

This chapter identifies the main adaptation strategies used by households in the study communities to reduce the adverse impacts of climate variability and change on their livelihood activities. It combines questionnaire surveys, key informant interviews and participatory methods (including FGDs and transect walks). The results show that households employ on-farm and off-farm adaptation strategies including changing the timing of planting, planting early maturing varieties, diversification of crops, relying on family and friends, planting drought-tolerant crops and changing diets as well as reducing food consumption to manage climate variability. The results reveal that most households use coping strategies that are linked to livelihood diversification. Most of these households engage in multiple non-arable farming livelihood activities in an attempt to avoid destitution because of crop failure linked to climate variability (particularly drought). Socioeconomic factors such as gender, age, perceived wealth, educational level and land tenure system as well as agro-ecological setting could influence the choice of adaptation strategies by households. The chapter concludes that these socioeconomic factors must be taken into consideration by policy makers in the design and implementation of climate adaptation policy. The findings suggest that policy makers need to formulate targeted climate adaptation policies and programmes that are linked to enhancing livelihood diversification, as well as encouraging households in different farming communities to share knowledge on climate adaptation.

6.1 Introduction

As already highlighted in Chapter 2, recent international efforts at finding solutions to climate change (i.e. the UNFCCC and the Kyoto Protocol) have recognised the role of adaptation as a policy option (Ford, 2007; Smit and Skinner, 2002; Pielke *et al.*, 2007). Particularly, Article 10 of the Kyoto Protocol and Article 4.1b of the UNFCCC commits parties to these treaties to promote adaptation to reduce the adverse impacts of climate change (Smit and Skinner, 2002). In 2001, the Marrakesh Conference of Parties established the Adaptation Fund aimed at financing adaptation initiatives by developing countries. Despite the significance attached to adaptation, only a few studies (e.g. Bryan *et al.*, 2013; Tachie-Obeng *et al.*, 2012) have explored the adaptation options implemented by farming households in SSA. This knowledge gap is important and needs urgent attention, because without an understanding of the adaptations that people are already making to cope with climate change, it is difficult to target policy support to further strengthen and upscale those actions. Against this background, the purpose of this chapter is to identify the main coping and adaptation strategies used by households in the study communities to mitigate against the negative impacts of climate change and variability on their core livelihood activities (i.e. agriculture). To achieve this aim, the specific objectives are to:

1. Identify and evaluate the main on-farm coping and adaptation strategies used by households in the study communities;
2. Determine the main off-farm coping and adaptation strategies used by households in the study communities;
3. Assess the main socioeconomic factors that may influence the choice of climate adaptation strategies by households in the study communities.

By meeting these objectives, this chapter contributes to academic debates by increasing our understanding of how small-scale farmers in Ghana and SSA more widely are coping with the challenges posed by climate variability and change. Having outlined the objectives of this chapter, the findings on the coping and adaptation strategies used by households in both the resilient and vulnerable communities are presented in the next sections.

6.2 Strategies to manage climate variability in study area

Adaptation strategies refer to long-term measures that involve changes in production and management decisions that are taken by households to reduce the adverse impacts of climate change and variability on their livelihoods (Smith *et al.*, 2000; Kelly and Adger, 2000). Coping strategies refer mainly to short term actions taken to counteract the immediate negative impacts of climate variability including drought (e.g. Campbell *et al.*, 2011; Yohe and Tol, 2002). Adaptation strategies employed by households to deal with drought in the study communities can broadly be grouped into two categories. The first group is on-farm adaptation strategies that refer to a series of agricultural management practices that are undertaken by households on the farm site aimed at reducing the adverse impacts of climate change and variability. Second, off-farm adaptation strategies refer to activities that are undertaken outside the farm in order to reduce the vulnerability of the household to climate change and variability.

The evidence from the questionnaire survey shows that households in the study regions are aware that climate change is happening. Specifically, households were asked about their observation of changes in rainfall and temperature patterns over the past approximately four-and-half decades (since the 1960s). The climate time span for perception studies was limited to the 46 years (i.e. from 1961–2007) due to restrictions on the availability of climate data (see Chapter 4, Section 4.4). However, this length of time is considered adequate to explore how household livelihoods have been impacted by climate variability. Table 6.1 shows that 78% of sampled households claimed to have observed increasing temperatures and that the weather has become hotter compared with their childhoods. In addition, about 90% of respondents indicated that they have observed considerable changes in the onset of the rains over the past 40–50 years.

In terms of rainfall, whilst about 82% of the sampled households perceived decreased rains, 18% reported increased rainfall over the study period. Most respondents were of the view that the rainy season in these communities was characterised by high intra-annual variability and torrential rainfall, which may not be that useful for rain-fed agriculture. Generally, there was almost unanimous agreement across the farming communities that there is a decreasing trend in the amount of rainfall as well as delays in the onset of the rainfall compared with their childhoods.

Farmers' perceptions of climate variability are increasingly being used in climate vulnerability and adaptation studies (see Maddison, 2007; Slegers, 2008; Mertz *et al.*, 2009). This is because farmers' perceptions based on their past experience and future expectations may influence the type of adaptation strategy used as a response to climate problems (Maddison, 2007). It has been suggested that farmers are more likely to adapt to climate change if they can perceive the changes in the climate (e.g. Maddison, 2007). Therefore, it is essential that these perceptions are assessed in a study such as this that seeks to explore the adaptation pathways of Ghanaian farmers to climate change and variability.

Table 6.1: Proportion of households in study communities who identified changes in climate

Variable	% of respondents who identified climatic changes		
	Resilient communities (*n*=135)	Vulnerable communities (*n*=135)	Average
(a) Rainfall			
Changes in onset	93.33	85.93	89.63
Increasing rainfall	21.22	14.07	18.15
Deceasing rainfall	77.77	85.93	81.85
(b) Temperature			
Increasing temperature	74.82	81.49	78.15
Decreasing temperature	5.93	4.44	5.19
Temperature unchanged	19.26	14.07	16.67

FGDs, key informant interviews, and questionnaire surveys (see Chapter 3) were used to elicit a broad list of on-farm and off-farm adaptation strategies in both resilient and vulnerable communities. Results are displayed in Table 6.2. This information was obtained in the broad context of how farmers perceived changes in rainfall and temperature patterns. Table 6.2 shows that households in the study communities used a broad range of on-farm and off-farm adaptation strategies to manage climate variability that can be applied by households elsewhere in Ghana and SSA more widely.

Households in dryland Africa are often confronted by multiple stressors including droughts, lack of markets, poor education and adverse economic development (Nielsen and Reenberg, 2010b). Although adaptation may be prompted by climate events such as droughts and floods, it should be acknowledged that these adaptation strategies are taken in response to the complex interplay of both climatic and non-climatic conditions including political, economic and socio-environmental changes (Mertz *et al.*, 2010). Therefore, it is quite difficult to attribute specific adaptation strategies to climate change and variability. Nonetheless, climate change and variability (particularly drought) is the major threat in dryland farming systems in Africa (UNDP, 2007), hence, the ability of the small-scale farmer in SSA in general to withstand drought is seen as critical in coping with other non-climatic stressors.

Table 6.2: Adaptation and coping strategies used by households in study communities

Adaptation strategies	Within resilient communities	Within vulnerable communities
On-farm adaptation and coping options	Changing the timing of planting Planting early maturing varieties Crop diversification Agro-forestry practices Crop rotation Planting drought-tolerant crops	Changing the timing of planting Planting early maturing varieties Crop diversification Planting drought-tolerant varieties Using irrigation facilities
Off-farm adaptation and coping options	Livelihood diversification Rely on friends and family Selling livestock Charcoal production Changing diets Governmental and NGOs assistance	Livelihood diversification Temporary migration Selling livestock Changing diets and reducing food consumption Governmental and NGOs assistance

An important element of these adaptation strategies came up during FGDs where farmers reported that adaptations may not all be implemented at the same time. Some, such as changing the timing of planting, irrigation and crop diversification happen during the farming season, while others such as selling livestock and labour migration happen after the farming season. Table 6.3 shows the temporal scale at which specific adaptation strategies may be implemented by farmers. Nevertheless, it must be emphasised that there may be overlaps between the different periods and actions.

Table 6.3: Temporal scale at which coping and adaptation strategies are operated

Time frame for climate adaptation		
Before the farming season	During the farming season	After the farming season
Livelihood diversification	Changing the timing of planting	Buying food or changing diet
Rely on social networks	Crop diversification	Selling livestock
Selling livestock	Planting early maturing crops	Temporary migration
Picking shea nuts	Using irrigation facilities	Picking shea nuts
Reducing food consumption	Planting drought-tolerant crops	Livelihood diversification
		Using irrigation facilities

6.3 On-farm adaptation and coping strategies

On-farm adaptation strategies involve changing agronomic practices to take advantage of the little rains for crop growth and development. These strategies include changing the timing of planting, crop diversification, planting early maturing and drought-tolerant crops and the use of irrigation facilities. These strategies are discussed in the following sections.

6.3.1 Changing the timing of planting

The results show that 92% (*n* = 248) of households interviewed in both the resilient and vulnerable communities reported changing their planting time in response to the delayed onset of the rains since the late 1980s. A focus group participant gave a characteristic response that illustrates the shift in timing of planting in these communities:

> "*When I started farming in the 1960s, I used to plant in late January or early February and the distribution of the rains was not as erratic as today. Since the late 1990s, I plant in March and sometimes even in April to be sure of good rains. Even with that you are not sure whether the rains will continue for the crops. Hence, the best time to plant in this community now is to wait for the second rain when you will be sure it will be sustained for enough rainfall for the crops"* [Female farmer, focus group participant, Babaso, July, 2010].

An analysis of the available rainfall data from the Ghana Meteorological Agency shows that the onset of the rains, which determines the beginning of the farming season in the study communities has changed (see Figures 6.1 and 6.2). Figure 6.1 shows that whilst the rains for planting by farmers in the resilient communities used to start in February in the 1960s through to early 1980s, this rainfall pattern changed and farmers had to wait until March since the late 1980s for the onset of the rains. A similar trend was observed in the vulnerable communities where farmers used to plant in March/April in the 1960 and 1970s but according to them, since the 1990s they have to wait until late May and early June to plant their crops (Figure 6.2). Focus group participants in the vulnerable communities claimed that they now plant their crops in early June to be more certain of adequate rainfall for crop growth and productivity.

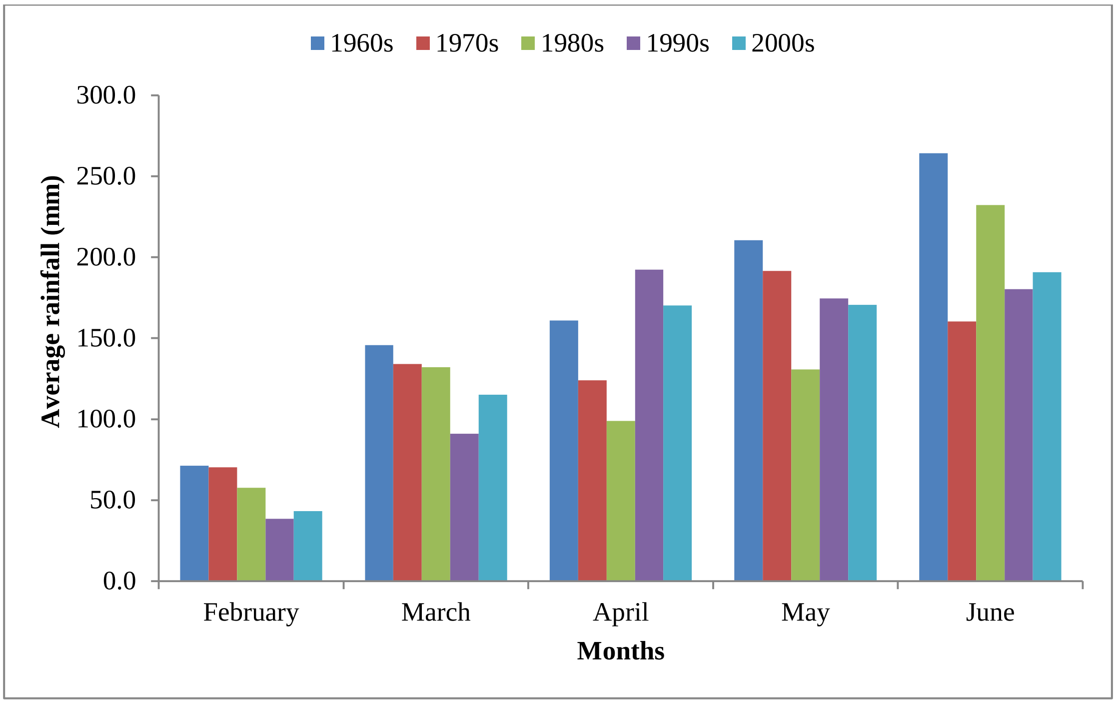

Figure 6.1: Average rainfall for the growing season in resilient communities

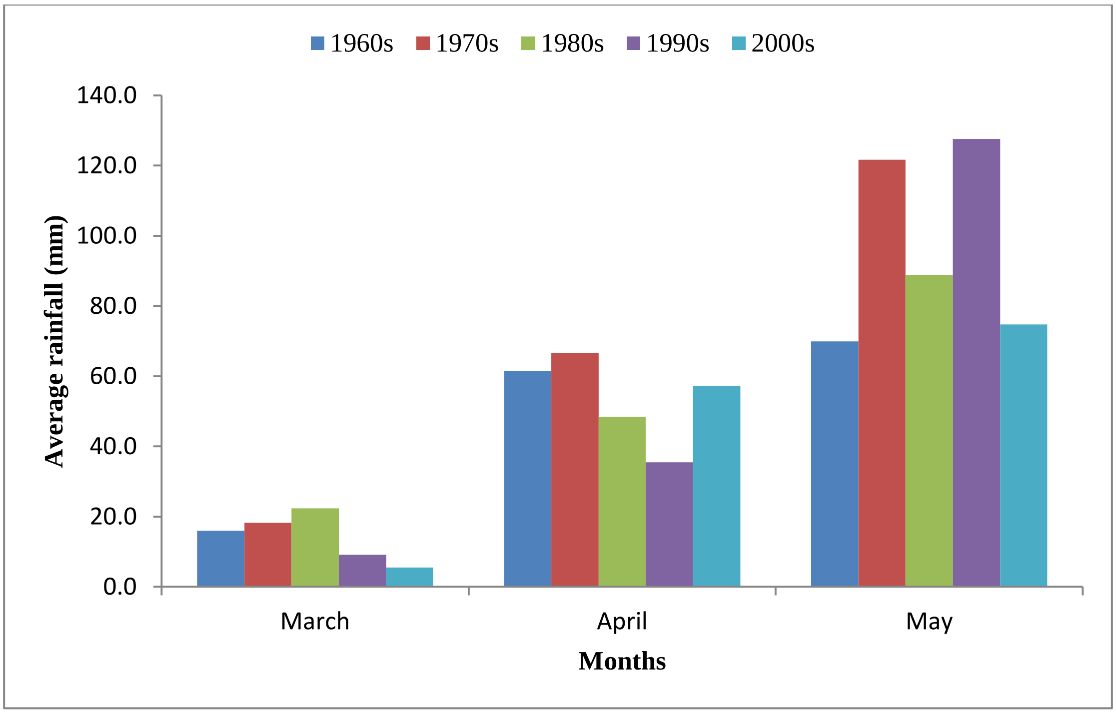

Figure 6.2: Average rainfall for the beginning of the season in the vulnerable communities

6.3.2 Planting early maturing varieties and changing cropping patterns

Planting early maturing varieties of crops has been one of the main adaptation strategies used by households in the study communities to reduce their vulnerability to climate variability. About 74% and 71% of households in the resilient and vulnerable communities respectively reported using this adaptation strategy. Households in the resilient communities have been planting early maturing varieties of maize such as *obaatanpa*, *okomasa*, *dobidi*, and *aborutia*, which are also drought-resistant. Households claimed that these varieties take between 70–90 days to mature compared with the traditional varieties, which could take 120–140 days. In the vulnerable communities, households reported planting early maturing varieties of millet and sorghum. According to them, by the time seasonal drought sets in, these drought-escaping varieties would have passed the most critical stages of their development such as flowering and tasseling, which require an appreciable amount of water to produce a good harvest. By maturing earlier, these varieties reduce the risk associated with climate variability. An extract from a household questionnaire open response illustrates the importance of planting early maturing varieties:

> *"We [most farmers in this village] are able to harvest our early millet in late July and this harvest is crucial for the survival of most households in this village. This first harvest after long period of stress is used to prevent hunger and destitution"* [Male farmer, Ayelbia, August, 2010].

Changing cropping patterns has also been used by households in the study communities to cope with climate variability. Though related to agricultural development more widely, climate change makes it more important for households in dryland farming systems to change the types of crops grown, as evidenced by the drought events of the 1983/84 that led to households in the resilient communities (particularly Nyamebekyere) to change their cropping patterns. For instance, the climate timeline constructed with farmers during FGDs (Table 6.4) highlighted that households were growing mainly cash crops such as cocoa when they first settled at Nyamebekyere. However, they changed their cropping patterns from mainly cocoa in the late 1960s to food crops such as maize in the 1970s, tobacco in the 1980s and have been growing maize, yam, and rice since the late 1990s (Table 6.4). According to farmers, these developments were in response to bush fires in the late 1960s that destroyed their cash crops and the droughts of 1983 which destroyed all food crops in this community.

Though households claimed to have changed their cropping patterns in response to climate variability, interactions with the farmers during transect walks and agro-ecological surveys revealed that farmers' responses might have partly been influenced by non-climatic factors such as economic shocks. For instance, it was gathered that the transition to tobacco growing in the Nyamebekyere community was influenced by the availability of ready markets for tobacco during the 1980s. Economic liberalisation as a result of structural adjustment programmes in the 1980s meant that there were good markets for tobacco. Similarly, the change in cropping practices from a predominantly tobacco growing era in the 1980s to growing maize, yam, and rice at Nyamebekyere was partly in response to the closure of the tobacco company in this community as a result of heavy tax levied on tobacco companies by the government of Ghana. Hence, households respond to climate variability within the full myriad of other non-climatic disturbances that affect rural livelihoods. This corroborates several studies (Reid and Vogel, 2006; Mertz *et al.*, 2010; Thomas *et al.*, 2007) that suggest that households in dryland farming systems respond to multiple stresses including both climatic and non-climatic drivers.

6.3.3 Crop diversification

Analysis of qualitative interviews shows that households are increasingly using diversification of crops as an adaptation strategy to reduce yield losses associated with unpredictable rainfall patterns in the study communities. The results show that about 79% (n = 214) of households (89% of households in the vulnerable and 69% in the resilient communities) reported using crop diversification as an adaptation strategy. Households claimed that the drought events of the 1983/84 farming seasons added another dimension to the need to diversify crops (see climate timeline in Table 6.4). Different crops have different physiological properties and hence may differ in their sensitivities to rainfall and temperature variability (Gliessman, 2007). Discussions with focus group participants indicated that farmers have very clear ideas as to why they were planting different crops at the same time, using it as a risk spreading measure against total crop failure.

Table 6.4: Climate histories[17] for resilient and vulnerable communities (1960-2007) based on focus group discussion with farmers

Timeline	1960s ⟶ 2000s
Onset of rains[18]	In resilient communities, focus group participants said rains used to start in February and even sometimes in January in the late 1960s. However, by the 2000s the rains do not come until March. In the vulnerable communities, rains used to start in March but since the 1990 the rains are delayed and do not start until May.
Amount of rains	In the resilient communities, farmers indicated that the rains were evenly distributed during the farming seasons in the 1960s and 1970s. In the 1980s, the rains started becoming a bit erratic but since the late 1990s, farmers argued that the amount of rainfall has generally reduced. In the vulnerable communities, FGD participants reported that rainfall was more in the 1960s and 1970s than the 1990s and 2000s. Since the late 1990s there is sometimes too much rainfall within a short period, leading to flooding.
Planting time	In the resilient communities, planting used to be in February in the 1960s and 1970s as soon as the first rains come. But since the late 1990s and 2000s farmers tend not to plant until March and April. In the vulnerable communities, planting time used to be in March/April in the 1960s through the 1970s. Since the 1990s, planting is done in May/June.
Type and varieties of crops grown	In resilient communities, farmers claimed they used to grow cocoa in the 1960s but bush fires destroyed this and started growing yam, rice and maize in the 1970s. Farmers started growing drought-resistant varieties of maize including *aburotia* and *dobidi* in the 1990s. In the vulnerable communities, farmers are now growing early maturing millet in response to drought in such communities.
Major climatic events[19]	In the resilient communities, there was a major bush fire that destroyed food crops and cash crops such as cocoa at Nyamebekyere and neighbouring communities in the late 1960s. A major drought in the resilient communities was 1983 drought that destroyed crops. The vulnerable communities have witnessed drought in 1983, 2002 and 2005. Some FGD participants also mentioned drought in the 1990s but could not be specific about the year. Also, households in the vulnerable communities experience seasonal drought. According to FGDs, recent major flood was in 2007.
Major livelihood activities[20]	In the resilient communities, farmers were mostly crop farmers in the 1960s and 1970s. In the 1980s, they were also tobacco farmers. In the 1990s, most farmers started rearing animals in addition to crop farming. In the mid 2000s, most farmers are now diverting into emerging livelihood activities such as charcoal burning and grass-cutter rearing. In the 1960s and 1970s, farmers in the vulnerable communities were only crop farmers. Since the late 1990 farmers started keeping livestock.

[17] Farmers found it difficult to give specific timelines. Local and national historical events were used to help them estimate major climate timelines in these villages.
[18] Quote: *"When I started farming in this village, the rains used to start in late January and I used to plant crops in February*." In the resilient communities, rainfall data suggest that average rainfall in February in the 1960s (1961-1969) was 71.4 mm, in 1990s (1990-1999) was 38.5 mm and in 2000s (2000-2007) was 43.2 mm. This shows that the average rainfall for February in the 2000s is approximately 61% of the average rainfall for February in the 1960s. This represents significant reduction in rainfall for February, which used to be the beginning of the farming season in the resilient communities in the 1960s and 1970s.
[19] Climate records show there were major droughts in 1983, 1995, 2002 and 2005 apart from seasonal droughts in the vulnerable communities.
[20] Quote: "*When I started farming in this village, I was growing only crops. I started keeping livestock in late 1990s and since 2000, my family has been producing charcoal [in addition to growing crops]"*

A female farmer at Aframso put it bluntly as:

"When one crop fails, for instance due to disease outbreak because of inadequate rainfall and increasing temperature patterns, I am likely to be compensated by the yield from other crops and avoid total crop failure…" [Aframso, FGD, 2010].

In areas where rainfall variability is a perennial feature, growing two or more crops on the same piece of land acts as a type of insurance against total crop failure. These results are similar to other studies that have been conducted elsewhere in SSA (Bryan *et al.*, 2013), suggesting that farmers are increasingly diversifying their crops to cope with climate variability.

6.3.4 Planting trees in agro-forestry systems

One of the adaptation strategies that relates broadly to climate change and variability is the use of agro-forestry systems. Focus group participants and key informant interviews suggested that growing trees was not part of the farming system in both the resilient and vulnerable communities in the early 1960s. However, since climate events such as bush fires in the 1960s and a major drought in 1983 that destroyed most crops, households began adopting the planting of trees as a way of coping with climate variability. Households claimed that since the 1980s, they had witnessed increased temperatures and started planting trees to improve the microclimate on the farm. The results of the household questionnaire survey show that 33% of households in the resilient communities reported using agro-forestry practices as climate adaptation strategy. A further 7% indicated that they have in the past marketed agro-forestry products such as trees and this has helped them achieve economic and food security. Emphasising the importance of agro-forestry systems as an adaptation strategy a farmer at Babaso noted:

> *"We also plant trees including teak and citrus as part of our farming activities because we have realised that the citrus plants are more drought tolerant, and when they are harvested, this often brings a lot of relief in terms of financial returns"* [Male farmer, household interview, Babaso, July, 2010].

These results are similar to studies by Jama *et al.* (2006) and Kebebew and Urgessa (2011) that suggest that in east and central Africa, agro-forestry provides opportunity for low-income farmers to enhance their livelihoods activities by selling the wood products as small timbers, medicines and food. The importance of agro-forestry practices as a climate adaptation strategy has been widely emphasised (Mcneely and Schroth, 2006; Kebebew and Urgessa, 2011). For instance, the integration of agricultural systems with trees on the same piece of land can ensure the complementary use of environmental resources which can enhance productivity (Stringer *et al.*, 2012). The ability of farmers to implement agro-forestry practices as adaptation strategy is partly linked to the kind of tenure system used by the households (see Chapters 5 and 7 on how land tenure constrains farmers' adaptation strategies).

6.3.5 Using irrigation facilities

Water system technologies including large-scale irrigation facilities are increasingly being used by households, especially those in the vulnerable communities (particularly Vea), to practise dry season vegetable farming. A key informant at Vea where there is a large-scale irrigation dam indicated that households are allocated land around the dam where they can grow vegetables such as tomatoes. Indeed, the use of irrigation facilities among small-holders can substantially reduce crop failure due to meteorological drought in dryland agricultural systems (e.g. Enfors and Gordon, 2008; Laube *et al.*, 2012). According to FGD participants, using irrigation as a way of coping with drought assumed greater importance especially in the vulnerable communities in the 1980s, when rainfall variability became predominant, leading to a shortened growing season. For instance, in the vulnerable communities without irrigation facilities, farming is only possible from June–October whilst in the 1960s and 1970s households could farm from March to November. The significance of the irrigation as an adaptation strategy is captured in the following remarks by a famer:

> *"Having land at the irrigation dam is crucial in this village. I grow vegetables such as tomatoes during the dry season when there are no rains to grow crops such as millet, sorghum and guinea corn. The money I get from the sale of these vegetables is used to buy food to feed my family* [Male farmer, Vea, July, 2011].

This narration shows that households rely greatly on the irrigation to cope with climate variability, especially during the dry season when there are no farming activities as farming in these communities is entirely rain-fed. During FGDs, farmers explained that though many of them were cultivating tomatoes during the dry season from November to May, most of them were confronted with difficulties in accessing credit and complexities associated with the land tenure system (see Chapter 7 for details).

6.3.6 Planting drought-tolerant crops

Another adaptation strategy used by households especially those in the resilient communities was the planting of drought-tolerant crops such as cassava (*Manihot esculenta)* and plantain *(Musa spp*.), which also have multiple uses. The use of drought tolerant crops has been reported as one of the major recommended adaptation strategies in food systems (Campbell *et al.*, 2011). For instance, households at Nyamebekyere and Babaso reported that the droughts events of 1983 triggered most of them to start growing these drought-tolerant crops. According to FGDs, households realised that maize, rice and other cereals were becoming more susceptible to climate variability, particularly drought. Farmers now grow cassava and plantain in addition to maize and rice. FGD participants claimed that these crops are more tolerant to drought compared with maize and rice and are therefore increasingly growing them. However, households recounted difficulties they faced with the production of these crops including the fact that they cannot be stored for very long time compared with maize and rice. Households also reported that there is a limited market for cassava and plantain compared with maize and rice. Culturally, there is preference for maize in these farming communities.

6.3.7 Crop rotation as an adaptation strategy

Though associated with agricultural development widely, crop rotation is a predominant practice, especially in the resilient communities. During the ecological surveys it was established that the resilient communities use crop rotation as a way of increasing diversity and maintaining soil fertility. The resilient communities have two farming seasons–major and minor–and therefore farmers divide their farm lands into two or three (depending on the number of crops) and grow the main crop in the main farming season (March–July) and change the crops during the minor farming season

(August–October). Rotational effects can be created as a result of alternating crops in time and this ensures that crops which are grown in a rotational fashion perform better in terms of yield compared to when these crops are grown in a continuous monoculture system (Gliessman, 2007). An extract from household qualitative survey response illustrates the significance of crop rotation:

> *"I plant maize in the major season and then plant groundnut in the minor season on the same plot. Rotating crops restores soil fertility, which eventually increases the productivity of the crops"* [Opinion leader, Aframso, July, 2010].

The addition of plant residues to the soil through crop rotation has the potential to stimulate the activities of different micro-organisms (Gliessman, 2007). Incorporating temporary diversity through crop rotation also has the potential to break the life cycles of diseases and insect pests that may affect crop growth and overall productivity (Altieri and Nicholls, 2005) and, which are likely to increase due to risks associated with climate change (Gan, 2004). The next section presents findings of the off-farm adaptation and coping strategies available to households in the study communities.

6.4 Off-farm adaptation and coping strategies

Households reported a number of off-farm coping and adaptation strategies in the study communities. These strategies, including livelihood diversification, temporary migration, reliance on social capital, information sharing on impending droughts, relying on governmental and non-governmental organisations and changing diet and reducing food consumption, are expanded on in the following sections.

6.4.1 Diversification of livelihood activities

In dryland crop production systems in SSA that are characterised by inherently high rainfall variability, diversification has been used as a key adaptation strategy to reduce the production risk associated with climate variability (Paavola, 2008; Ellis, 1998; Dinar *et al.*, 2008). Table 6.5 shows that households in the study communities were engaging in multiple non-arable farming livelihood activities in response to rainfall variability. Households claimed that they were diversifying livelihood activities more today compared with the 1970s. A climate timeline developed in these communities suggest that most of the farmers were mainly crop farmers in the 1960s through the early 1980s (Table 6.4). An extract from a key informant interview illustrates this:

> *"More households in this village are now engaging in non-farm income jobs than we used to do in the early 1970s. During the 1970s, most of the households were mainly crop farmers with few farmers keeping livestock in addition to crops. After the droughts of 1983/84, most households began moving into non-farm jobs that are less dependent on rainfall"* [Key informant, Vea, July, 2011].

Table 6.5: Types of non-farm jobs undertaken by sampled households in study communities (excluding jobs cited by less than 1% of the sample households)

Livelihood strategies	**Percent of households engaged in non-farm livelihood activities**	
	Within resilient communities (*n* = 135)	Within vulnerable communities (*n* = 135)
Petty trading [f]	28.15	14.81
Salaried employment	3.70	1.48
Tailoring	2.22	0.00
Forest assistants [m, r]	9.63	0.00
Bicycle repairer [m]	0.00	2.96
Selling livestock	10.37	18.51
Charcoal burning [f, r]	8.89	0.00
Carpenter [m]	2.22	0.00
Food vendor [f]	5.92	0.00
Masonry [m]	2.22	0.00
Grass cutter rearing	2.22	0.00
Fishing [m, v]	0.00	6.67
Casual labour [m, v]	0.00	2.22
Sand mining [m, v]	0.00	5.92
Weaving [v]	0.00	14.82
Shea nut picking [f,v]	0.00	2.96
Pito brewing [f, v]	0.00	2.96
Others	6.67	3.70

[m] Male-dominated, [f] female-dominated, [r] mostly in resilient households, [v] mostly in vulnerable households. The percent of male and female-headed households that reported using particular non-farm jobs was used to arrive at whether a response was female or male dominated. The 'others' in the table include activities such as firewood harvesting and household asset selling. Testing for significance in terms of livelihood diversification in agro-ecological setting is provided later in this chapter.

The results suggest that periods of food insecurity and stress, which start some few months after the harvest and reach their peak during the dry season between January and June, especially in the vulnerable communities, is mediated by the engagement of households in a number of non-farm activities. Petty trading dominated the non-farm jobs with 28% and 15% of households in the resilient and vulnerable communities respectively indicating that they engaged in petty trading (Table 6.5).

About 19% and 10% of households in the vulnerable and resilient communities respectively reported selling livestock (mostly goat and sheep) and poultry to cope with drought in the last five years (i.e. 2005–2010) (see, Table 6.5). Selling livestock is dominated by male farmers and also dependent on the capital outlay that can be invested in livestock production by a household. For this reason, rich households including outlier households in the vulnerable communities that may have access to credit and other forms of funds are able to invest in livestock production (see Case 5 in Table 5.4). Key informants claimed that selling livestock is one of the most profitable non-farm activities in the vulnerable communities. According to them, livestock production is less vulnerable to drought compared with crop production.

Grass cutter rearing is also an emerging non-farm activity in the resilient community, especially Babaso. Additionally, since the early 2000s, households claimed that charcoal production is becoming an important and emerging non-farm coping strategy, especially amongst the households in the resilient communities, in which about 9% of households engage in it to raise funds to support the household (Table 6.5). Indeed, this may well be an underestimate because charcoal production involves the illegal felling of trees and households may not want to state that they are involved in such activities. In the vulnerable communities, basket and hat weaving, shea nut picking and dawadawa processing constitute important non-farm activities. The shea nuts are processed into shea butter and exported for foreign income. About 6% of households (mainly male-headed in the vulnerable communities) reported engaging in sand mining activities as a coping strategy during drought (Figure 6.3). Despite the environmental degradation associated with this activity it is emerging as one of the main coping strategies during the dry season, especially for male farmers at Vea. Farmers claimed that they are able to fill between 3–6 trips of sand which are sold at GHc10.00 [US$6.67] per trip. The total amount raised is shared among the members of the sand mining association and this helps them to buy food for their families during the dry season.

A critical examination of the results suggests that engagement in a specific non-farm livelihood activity may be determined by the gender of the respondent and that livelihood activities may be clustered into three groups: (i) those that are pursued predominantly by females; (ii) those pursued predominantly by males; and (iii) those that are gender blind (i.e. those engaged in by both females and males). Non-farm activities such as petty trading, shea nut gathering and pito brewing are specifically undertaken by women. For instance, while 72% (n = 42) of the respondents that indicated petty trading were females, only 28% (n = 16) were males. On the contrary, selling livestock, sand mining, being a forest assistant, bicycle repairer and fishing are predominantly engaged in by males. None of the 39 respondents that reported selling livestock as a non-arable livelihood activity was a female. Activities such as charcoal processing and weaving are gender-blind. According to focus group participants, the women trade in different things including foodstuffs, meat, general wares, provisions, farm inputs and implements, cooking utensils and cooked food.

Figure 6.3: Sand mining by male farmers at Vea, August, 2011

6.4.2 Relying on friends and family to cope with climate variability

In rural agriculture-dependent communities, households depend to a greater extent on social networks. About 36% (*n* = 96) of households claimed to have relied on friends and families at least once in the last five years (i.e. 2005–2010) to cope with the impacts imposed by the changing weather patterns on their livelihood activities. Households rely on social networks including farmer-based associations and faith-based organisations (such as churches) that offer assistance in the form of food in times of crisis and also assist members to secure loans. Generally, households in the resilient communities had more opportunities for greater social integration compared with those in the vulnerable communities. Transect walks and personal interactions with members of the community revealed that the type of settlements in the study communities may greatly influence the extent of social networks and interactions. The vulnerable communities have sparse settlements that may not enhance social integration. In such communities, individual households settle on a piece of land and practise compound farming (cultivating the land around the close vicinity of the homestead). There are therefore wider distances among various homesteads and fewer interactions among the households in the vulnerable communities. On the contrary, households in the resilient communities have clustered settlements that enhance social interaction and inculcate a higher sense of belonging and greater level of social cohesion. Hence, there are regular and frequent social contacts among different households. It was discovered during FGDs that social networks can provide a range of benefits, e.g. the sharing of information of impending droughts and the opportunity to engage in temporary migration.

6.4.3 Agro-ecological knowledge on impending rainfall and droughts

Particularly interesting is the reliance of households on their social networks to share indigenous agro-ecological knowledge on early warning signs for climate forecasting – an essential aspect in coping with and adapting to climate variability and change. Studies have shown that local farmers in SSA have rich and sophisticated agro-ecological knowledge that could be useful information for climate adaptation (e.g. Nyong *et al.*, 2007; Orlove *et al.*, 2010; Speranza *et al.*, 2010). In all, 59% and 72% in the resilient and vulnerable communities respectively reported using their traditional agro-ecological knowledge to cope with climate variability. Qualitative interviews with farmers suggest that they use their agro-ecological knowledge to develop complex mental climate models that are based on the happenings of their surroundings. Such traditional climate models are used to design seasonal calendars that facilitate adaptation by way of planning their agricultural activities such as when to plant their crops. This is very crucial in rain-fed dryland farming systems where crop yields could be seriously affected if farmers miss key activities in the calendar season.

Specific agro-ecological knowledge on early warning indicators for both impending rainfall and dry spells in the study communities highlighted during FGDs and ecological surveys varied (Table 6.6). Households in the vulnerable communities use the flowering and fruiting of trees such as the baobab tree (*Adansonia digitata*), and *Vitellaria paradoxa* (shea tree) to indicate the onset of the rains and prepare their farm lands. In the resilient communities, farmers use the flowering of *Ceiba pentandra* to signify impending rainfall (Table 6.6). Some households also use the direction of the wind to indicate impending rains for agricultural purposes. Still others rely on past rainfall patterns including the start and ending of the rainy season to form expectations and predict the rainfall patterns for the coming season.

Table 6.6: Early warning indicators used by farmers for impending rainfall and dry spell

Impending rains	Impending dry spell (drought)
Flowering of *Daniella spp* (hyedua)	Ripening of the leaves of *Ceiba pentandra*
Flowering of *Adansonia digitata* (Baobab)	Appearance of "cattle egrets" (migratory birds)
Flowering of *Vitellaria paradoxa* (shea tree)	Ripening of *Bombax buonopozense's* leaves
Flowering of the *Tamarimdus indica* tree	Fruiting of the *Daniella spp* (hyedua) tree
Flowering of the *Bombax costatum* tree	Appearance of hawks in the community
Appearance of leaves on the *Leanea acidia* tree	Land becomes very dry
Appearance of bats in the community	Cricket crying
Appearance of leaves on *Anogeissus leiocarpus*	Flowering and fruiting of the *Parkia biglobosa*
Appearance of leaves on *Faidherbia albida tree*	(dawadawa) tree

6.4.4 Temporary migration

Temporary migration has long been part of the history of households in northern Ghana (Rademacher-Schulz and Mahama, 2012; Van der Geest, 2011; Pickbourn, 2011). However, droughts over the last 40 years (since the 1970s) have added a greater dimension to the importance of temporary migration as a climate adaptation strategy more widely in SSA (Findley, 1994; Nielsen and Reenberg, 2010a; Mortimore and Adams, 2001). About 91% (*n* = 123) of the households sampled in the vulnerable communities indicated that at least one member of their household had migrated within the last 5 years (i.e. from 2005–2010) as a strategy to cope with climate variability.

Focus group participants claimed that after harvesting in October/November, many of the farmers, mostly the younger ones, leave for southern Ghana, especially Ashanti and Greater Accra regions, where the climate conditions and job opportunities are better. The Greater Accra and Ashanti regions also have two farming seasons that make ideal farming conditions for these migrants. Qualitative data suggest that when farmers have depleted their food reserves during the dry season, they either migrate or call on the assistance of their family members who have migrated to southern Ghana to salvage the situation and prevent total destitution. Once in southern Ghana, the majority of these migrant farmers mostly work as (i) labourers in other people farms, (ii) watchmen or security officers and; (iii) head porters ("*kayayei*") (Awumbila and Ardayfio-Schandorf, 2008). It is significant to stress here that these activities are all low income non-farm livelihoods opportunities. Most of these migrant farmers find it extremely difficult to obtain employment in the formal sector because of their lack of skills and low educational standards (see Table 5.3).

Farmers were asked to provide reasons why they or members of their households migrated out of these communities. The results show that farmers migrated in response to drought and other harsh environmental conditions as well as socioeconomic pressures. This is detailed in a typical comment by a farmer:

> *"We migrate to the south to work as labourers so that we can send monies to our families to buy food [to cope with drought]. From November to May, there is no farming in this village as we depend entirely on the rains for our farming activities. You cannot stay here and starve so the best option is to migrate to work on people's farm to get money. When there is drought, you have nothing to eat; the only option is to migrate*" [Male farmer, Adaboya, August, 2010].

Recurrent droughts coupled with inherently poor soil fertility in the vulnerable communities (Quansah, 2004; Oteng *et al.*, 1990) have contributed to significant reductions in agricultural productivity over the years. For instance, data from MoFA suggest that average yields for millet and sorghum were 1.06 mt/ha and 1.27 mt/ha respectively for 1995, compared with 0.96 mt/ha and 1.06 mt/ha for the same crops in 2008. Soils in the Bongo district and the savannah zone of Ghana in general are deficient in nitrogen, phosphorus and sulphur (Oteng *et al*., 1990). Emphasising the extent of drought-induced migration, a key informant stated:

> *"Our youth are all moving to southern Ghana in search of job opportunities [and good farming conditions] because in this village the farming season is only from late June to October and after that there is no work for our youth. The environmental conditions are so harsh and do not make farming attractive any longer to our youth"* [Key informant, Vea, August, 2010].

Emanating from these observations is the fact that farmers in these communities migrate partly due to the absence of adequate rainfall which leads to drought and eventually famine. Nonetheless, these farmers are confronted with other socio-political and economic challenges that could partly influence the decision to migrate (Yaro, 2006). These results confirm several studies that indicate that people migrate in response to harsh climate conditions as a coping mechanism (McLeman and Smit, 2006; Myers, 2002; Gemenne, 2011). Studies by Rademacher-Schulz and Mahama (2012) and Van der Geest (2011) also suggest that environmental factors including shifts in rainfall seasons and increased intensity and frequency of droughts are among the key drivers for migration of farmers from northern to southern Ghana.

Power is also manifested within the vulnerable communities in relation to temporary migration. For instance, during FGDs, it was discovered that due to cultural norms, men were more likely to migrate compared with women. Key informants indicated that while men can migrate without necessarily seeking approval from their wives, married women need approval from their husbands before they can migrate to southern Ghana to seek better livelihoods opportunities. Such findings are consistent with results of Rademacher-Schulz and Mahama (2012) that suggest that social and cultural norms constrain female migration compared to male migration in the Nadowli district of

Ghana. It was discovered during FGDs that many of these farmers only move temporarily during the peak of the drought from November to May when there is no rainfall for farming activities and they move back to their communities when the rains start. The migration by these farmers can therefore be described as circular migration (i.e. migrants who stay less than six months in their new location and return to their home) (Findley, 1994).

6.4.5 Governmental and non-governmental assistance

Government and non-governmental assistance have also been very useful in helping households to cope with shortfalls in agricultural production triggered by extreme climatic events such as droughts and floods in the study communities. Out of the 270 households interviewed, 141 (representing 52%) indicated receiving some form of assistance from the government and NGOs such as World Vision International. About 36% and 68% of households in the resilient and vulnerable communities respectively reported that the government and other NGOs have been of help in one way or another. This shows that households in the vulnerable communities rely more on government assistance compared with their counterparts in the resilient communities.

As part of the survey, households were asked about the kind of assistance they have received from the government. Households received subsidies on fertilizers and food items. Key informants at the vulnerable communities claimed that during the 2007 floods that destroyed several houses, the government through the National Disaster Management Organisation provided relief items including food, mattresses and iron sheets. Households in the resilient communities also reported receiving assistance from the government to cope with the 1983/84 major drought that destroyed their crops. Households claimed that the government supplied them with food items including rice to cope [albeit over a short period] with the drought.

6.4.6 Changing diets and reducing food consumption

Changing diets and reducing food consumption have also become an important coping mechanism for households in the vulnerable communities. The results show that 73% (n = 99) of the 135 households sampled in the vulnerable communities have changed their diets as a coping strategy in response to drought induced food insecurity.

Households reported that they have often relied on food supplies from NGOs and governmental agencies during extreme events and therefore do not have an influence on the choice of food. A woman remarked during a household interview:

> *"If your family is starving because of drought, do you think of the kind of food that you are given? It may not be your favourite food but you have to try to eat what is available"* [Female farmer, qualitative interview, Ayelbia, 2010].

Related to changing diet is the reduction in food consumption by the members of the households. Since the 1990s when rainfall became more erratic (thereby affecting crop production), households in the study communities reported that reducing food consumption has become a key coping strategy during the dry season when families have run out of food supplies. Overall, 77% (n = 104) of households in the vulnerable communities reported reducing food consumption to cope with drought induced food insecurity. This contrasts with 18% (n = 24) of households in the resilient communities that reduced food consumption as a coping strategy. This needs to be critically evaluated as a coping strategy because reducing food consumption can also have serious consequences on the health of such households, which rather make them more vulnerable to the adverse impacts of climate variability. For instance, it will predispose them to various ailments that will make them more vulnerable in the face of changing climatic patterns (Heltberg *et al.*, 2009). What follows next is a quantitative analysis aimed at understanding the socioeconomic factors that influence household's choice of adaptation strategy.

6.5 Socioeconomic factors influencing the choice of adaptation strategies

Thus far, the adaptation strategies used by households in the study communities have been identified and evaluated in this chapter. By using a one-way ANOVA and t-test, where possible (Kinnear and Gray, 2012), this section explores the various socioeconomic factors that may influence the choice of an adaptation strategy by households in the study communities (for the ANOVA, see Chapter 3 for details on dependent and independent variables). Where significant differences existed between various communities and regions, the least significant difference (LSD) and Duncan post-hoc tests were used to separate the means of the various communities. An understanding of how socioeconomic characteristics affect adaptation strategies is crucial for the design of climate adaptation policies.

By exploring the total number of a particular adaptation strategy used by a particular socioeconomic group, two significant results emerged from the quantitative analysis. First, the results revealed that socioeconomic factors such as gender, age of the household's head, land tenure system, education, wealth (as perceived by the local community) as well as agro-ecological setting (i.e. whether a particular community is located at the resilient or vulnerable region) could potentially influence the choice of a particular climate adaptation strategy by a household. These results corroborate previous studies (e.g. Below *et al.*, 2012; Deressa *et al.*, 2009; Bryan *et al.*, 2013) that suggest that socioeconomic factors such as gender, age, education and agro-ecological setting could significantly influence a household's choice of a particular adaptation strategy. Second, unlike these studies, the results suggest that socioeconomic factors such as farm holding and the household size were not statistically significant at influencing the choice of a particular adaptation strategy. In the following sections, this thesis investigates why socioeconomic factors such as gender, age, education, wealth, land tenure and agro-ecological setting were significant in influencing household's choice of climate adaptation strategies.

6.5.1 Gender of the household head

The results showed that the gender of the household head statistically influenced the choice of agro-forestry and indigenous knowledge as adaptation strategies ($p < 0.05$) (Figure 6.4). By contrast, changing the timing of planting, crop diversification, planting drought tolerant varieties, livelihood diversification, relying on family and friends, and reducing food consumption were not significantly influenced by the gender of the household head. Overall, more male-headed households reported using agro-forestry as an adaptation strategy compared with female-headed households (Figure 6.4). Perhaps, this difference could be attributed to the fact that female-headed households in the study regions, especially those in the vulnerable communities, generally have small farm holdings because of the complex tenure system (Yaro, 2010). Considering the fact the agro-forestry products take so long to be harvested, female-headed households will be less inclined to commit part of their farm lands to this strategy.

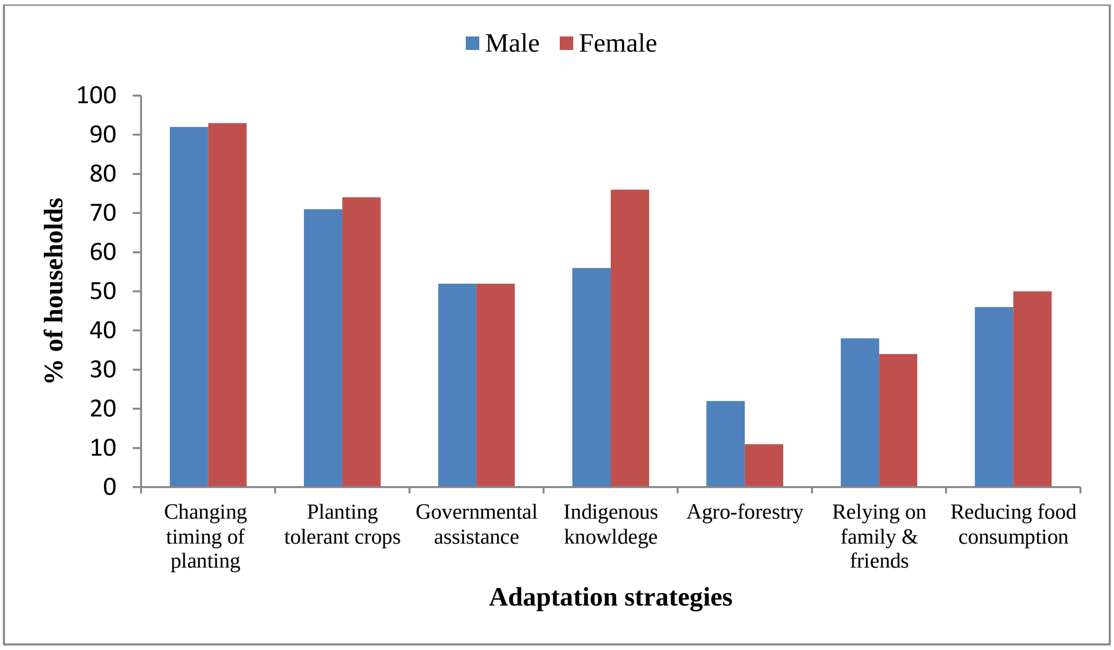

Figure 6.4: Proportion of male and female-headed households who reported using a particular adaptation strategy. Using agro-forestry and indigenous knowledge were significantly influenced by the gender of the household's head ($p < 0.05$).

6.5.2 Age of the household head

The results also demonstrate that the age of the household's head was not statistically significant at influencing the choice of adaptation strategies such as changing the timing of planting, using irrigation, crop diversification, relying on family and friends, temporary migration, livelihood diversification and governmental assistance. By contrast, the age of the household's head was significant in determining the choice of planting drought tolerant varieties as an adaptation strategy ($p < 0.05$) (Figure 6.5). The results reveal that more households that were headed by relatively younger farmers (i.e. 21–40 years and 41–60 years) reported planting drought-tolerant varieties compared with those above 60 years (Figure 6.5). This could be attributed to the fact that older farmers (i.e. above 60 years) were more inclined to use the traditional varieties of crops which they are used to, compared with improved varieties that may be drought-tolerant.

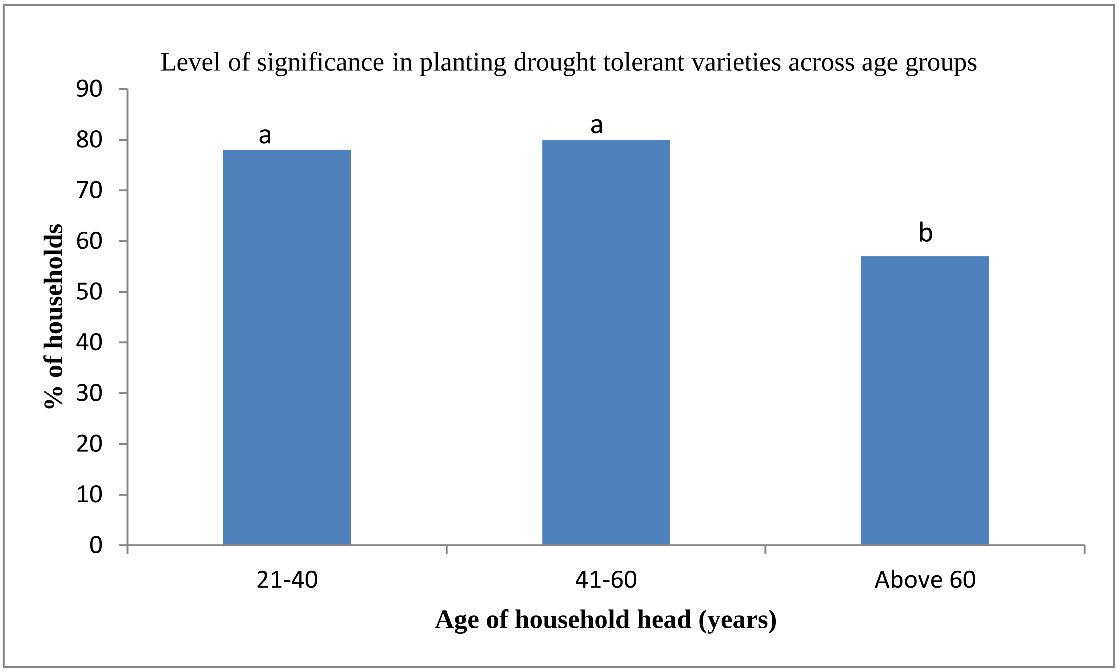

Figure 6.5: Proportion of households within different age groups planting drought tolerant varieties. Households headed by farmers within the age groups 21–40 and 41–60 years were significantly different from those above 60 years ($p < 0.05$).

6.5.3 The perceived wealth of the household

Additionally, the wealth of the household (as perceived by the local community) was statistically significant at influencing temporary migration and livelihood diversification ($p < 0.05$) (Figure 6.6). The results suggest that households perceived to be rich by the local communities rely more on livelihood diversification compared with poor households (see also, Chapter 5). Poor households are more likely to rely on family and friends during drought-induced food insecurity in the study communities. This could be explained by the fact that richer households tend to diversify their livelihoods activities and hence are less likely to rely on family and friends. Households who diversify their livelihoods create a wide-ranging portfolio, which they can fall on in times of crisis (Ellis, 1998; Paavola, 2008).

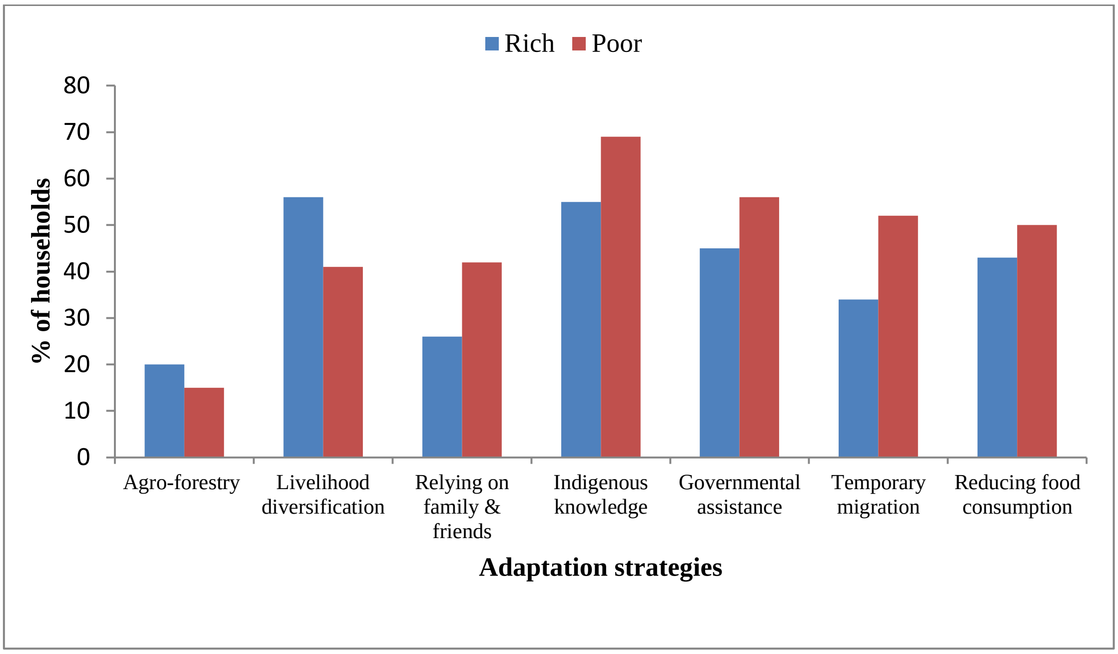

Figure 6.6: Proportion of households belonging to different wealth groups using different adaptation strategies. Livelihood diversification and temporary migration were significantly influenced by the perceived wealth of the household ($p < 0.05$).

6.5.4 The land tenure system of the household

The land tenure system of a particular household also influenced the choice of agro-forestry as an adaptation strategy ($p < 0.05$). On the contrary, the type of tenure system of a particular household did not significantly affect the choice of adaptation strategies such as crop diversification, temporary migration, reducing food consumption, planting early maturing varieties, using irrigation, livelihood diversification and using indigenous knowledge. Data from household questionnaire and ecological surveys suggest that the majority of households renting their farm lands (i.e. tenant farmers) were using short-term soil conservation practices, whilst households who have inherited their farm lands (owned lands) used both long-term conservation practices and adaptation strategies such as agro-forestry practices. For instance, whilst 22% of households that inherited their farm lands reported using agro-forestry as an adaptation strategy, only 8% of households that rented their farm lands reported using agro-forestry. This finding confirms studies suggesting that insecure land tenure systems may hinder farmers in practising long-term soil conservation techniques (Damnyag *et al.*, 2012; Toulmin and Quan, 2000; Adjei-Nsiah *et al.*, 2006). During qualitative interviews, households that were renting farm lands claimed that the customary tenure system prohibits them from planting trees that could last longer than annual food crops and there are no immediate returns on such plantation crops to non-owner farmers. This has serious implications for adaptation to climate variability because land tenure arrangements in the study regions constrained tenant farmer’s efforts at implementing appropriate adaptation strategies to mitigate the adverse effects of drought on their livelihoods.

6.5.5 The level of education of the household head

The analysis further shows that the level of education of the household head (or the most educated member of the household) significantly affected adaptation strategies such as livelihood diversification, temporary migration, indigenous knowledge, planting drought-tolerant varieties and reducing food consumption ($p < 0.05$) (Figure 6.7). By contrast the level of education did not significantly influence adaptation strategies such as changing the timing of planting, using irrigation, planting early maturing varieties, governmental assistance and relying on family and friends. Figure 6.7 shows that households that were headed by farmers with relatively better formal education (i.e. secondary education and above) tend to diversify their livelihood sources more than those without any formal education. Furthermore, a greater number of households with no formal education reported reducing food consumption to cope with drought induced food insecurity compared with those with secondary education (Figure 6.7). Good education may increase the income earning potential of a farmer and their households and thereby increase adaptive capacity including the adoption of new agricultural technology and access to information, which can potentially reduce the overall vulnerability of such farmers (Paavola, 2008; O'Brien *et al.*, 2004a; see Chapter 5). In addition, education can significantly influence temporary migration because farmers who have at least secondary education are more likely to have alternative livelihood options and hence less likely to migrate to other parts of the country to work as farm labourers (see outlier household Cases 4 and 7 in Table 5.4 in Chapter 5).

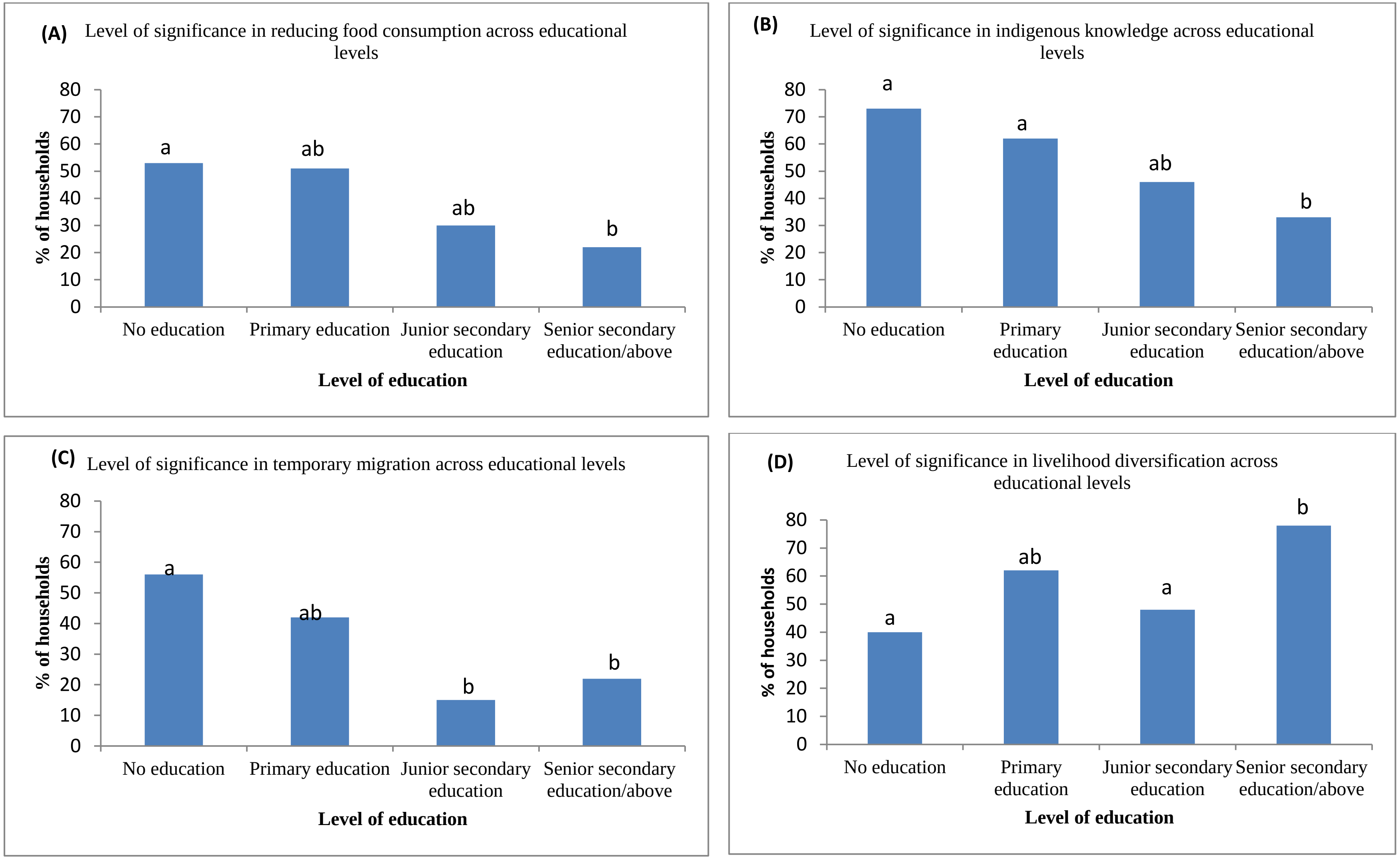

Figure 6.7: Proportion of households with different educational levels that reported using specific adaptation strategy. Level of education was statistically significant at influencing reducing food consumption, indigenous knowledge, temporary migration and livelihood diversification ($p < 0.05$). Bars with different superscript letters (a or b) are statistically significant at 5% for that particular adaptation strategy.

6.5.6 The agro-ecological setting of the household

Equally significant is the fact that adaptation strategies were statistically influenced by agro-ecological settings (the type of community) (Figure 6.8). For instance, the agro-ecological setting of a particular household influenced livelihood diversification, temporary migration, crop diversification, reducing food consumption, using indigenous knowledge, agro-forestry practices, governmental assistance and relying on family and friends ($p < 0.05$) (Figure 6.8). By contrast, the type of community was not statistically significant at influencing the choice of adaptation options such as changing the timing of planting and planting drought-tolerant varieties. Households in different agro-ecological settings are likely to be influenced by different climate and soil conditions that could potentially affect the use of a particular adaptation strategy.

The results show that households in the resilient communities (i.e. Aframso, Babaso, and Nyamebekyere) are more likely to diversify their livelihoods compared to those in the vulnerable communities (i.e. Adaboya, Ayelbia and Vea) (see Section 6.4.1 for details on livelihood diversification). These differences could be accounted for by the availability of alternative livelihoods and the relatively better educational standards of the farmers in the resilient communities (see Table 5.3). Another possible explanation for the significant difference between the two study regions in terms of livelihood diversification is the fact that households in the resilient region have relatively better rural infrastructural development such as markets and road networks that allow them to engage in non-farm livelihood activities (Zhang *et al.*, 2007).

Further, the significant differences observed for temporary migration across the two study regions could be linked to the differences in the level of infrastructural developments in these regions. This is because the lack of rural development in the vulnerable communities in terms of markets and institutional support (Whitehead, 2006) results in significant migration of farmers from the vulnerable region to southern Ghana in search of job opportunities. This is especially so during the peak of the dry season when there are no rains for farming activities. These findings are similar to a study by Deressa *et al.* (2009), suggesting that different farmers in different agro-ecological settings in the Nile Basin of Ethiopia employed different adaptation strategies based on the differences in soil and climatic factors.

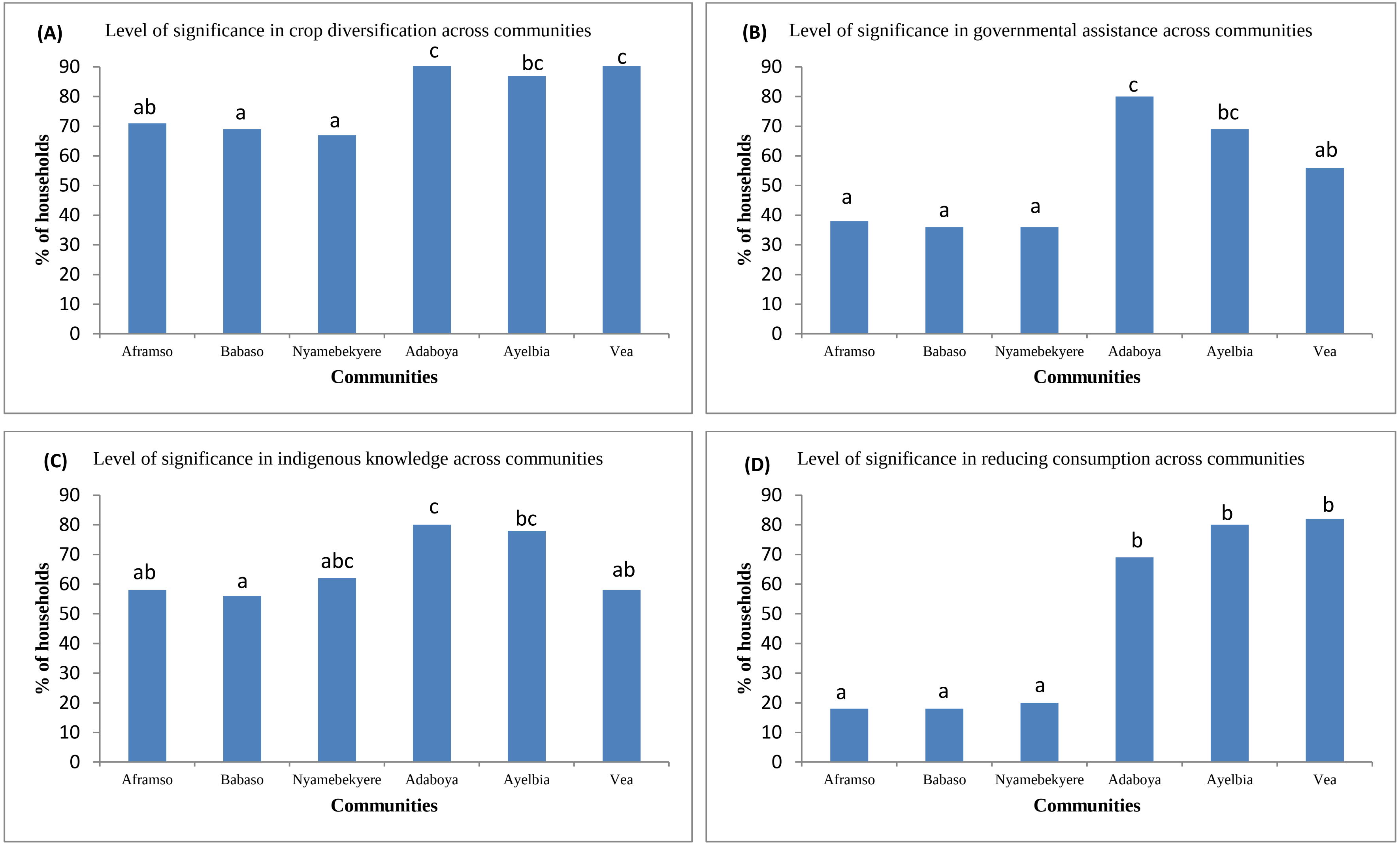

Figure 6.8: Proportion of households that reported using specific adaptation strategy in different communities (i.e. agro-ecological settings). Bars with different superscript letters (a, b or c) are statistically significant at 5% for that particular adaptation strategy. Aframso, Babaso and Nyamebekyere represent the "resilient" communities while Adaboya, Ayelbia and Vea are the "vulnerable" communities.

6.5.7 Summary on the socioeconomic quantitative analysis

Combining quantitative analysis with the qualitative insights (Sections 6.3 and 6.4) has provided a holistic understanding of the different dimensions of the problem posed by climate change and how this can be addressed. The quantitative analysis demonstrates that different adaptation strategies are influenced by different household socioeconomic characteristics. Similarly, none of the socioeconomic characteristics influenced all the various adaptation strategies. Most often, many adaptation strategies have not been effective because policy makers have failed to understand how household socioeconomic factors could influence the choice of adaptation strategies. Hence, they have often designed one-fit-all adaptation strategies that fail to yield the desired results. The results presented here are quite useful in that they provide policy makers with valuable information regarding how different household socioeconomic factors could determine the appropriateness of a particular adaptation strategy in the study communities. Importantly, this highlights the need for a comprehensive understanding of the local context within which climate adaptations are undertaken. Therefore, policy makers need to evaluate information on socioeconomic factors in the design and implementation of appropriate adaptation strategies in the study regions and more widely.

6.6 Discussion

The results presented in this chapter provide useful insights into the structure of the major on-farm and off-farm adaptation strategies that are employed by households to manage the adverse impacts of climate change and variability. It has been observed in the literature that agro-forestry systems provide both mitigation and adaptation measures to climate change (Nyong *et al.*, 2007). On the mitigation side, it has been documented that agro-forestry systems can sequestrate carbon and thereby mitigate the greenhouse effect by reducing the carbon emissions into the atmosphere (Mcneely and Schroth, 2006; Albrecht and Kandji, 2003). For example, it has been reported that an estimated 1.1–2.2 Pg C could be sequestered from the atmosphere by agro-forestry systems if agro-forestry systems were to be implemented on a global scale by the year 2053 (Albrecht and Kandji, 2003). This is because the inclusion of trees in agricultural ecosystem provides opportunity to increase the carbon sinks available (Dixon, 1995).

These results on livelihood diversification as a coping and adaptation strategy corroborate other studies (e.g. Ellis, 1998; Barrett *et al.*, 2001; Paavola, 2008) that suggest households may pursue non-farm livelihood activities as a way of spreading the risk associated with crop failure due to erratic rainfall patterns. Livelihood diversification could increase the asset base of households in dryland farming systems. This will enable such households to insulate themselves against adverse impacts of climate changes as well as economic shocks, thereby reducing their overall vulnerability to food insecurity (Ellis and Allison, 2004). Hence, by augmenting their livelihood activity portfolio, the smallholder farmer in dryland farming systems in SSA will be reducing the risks of an overall adverse livelihood outcome or production failure (Fraser *et al.*, 2005; see Chapter 5). This contributes to livelihood resilience at the household level (Osbahr *et al.*, 2008).

Households reported engaging in multiple non-arable farming activities such as petty trading, selling livestock, weaving and charcoal production to complement agricultural activities. These non-farm livelihood activities could be described as complementary activities as crop production remains the main livelihood activity for such households. Farmers reported that the profits from livestock sales are invested in foodstuffs to keep the household food secure after they have run out of provisions from their own farms. Focus group participants reported that part of the income from selling livestock is also invested in agricultural production in terms of buying farm inputs. Such claims by farmers are consistent with other findings that suggest that income from non-farm activities such as artisanal diamond and gold mining in Sierra Leone are invested to revive agricultural production (Maconachie, 2011). Households claimed that selling livestock is one of the most profitable non-farm activities in the vulnerable communities. Emphasising the significance of livestock to households, focus group participants indicated that livestock can be easily sold during crisis, especially during the lean season, to raise money for the family compared with crops because there is a ready market for livestock. These views are consistent with that of Reardon *et al.* (1988) and Hesselberg and Yaro (2006) who suggested that in most agriculture-dependent rural African households, the availability of livestock represents wealth and serves as an important insurance mechanism because households can easily sell livestock to buy grain.

The results further indicate that women engaged in non-farm livelihood activities such as petty trading, pito brewing, shea nut processing and weaving to raise extra income to make sure there is food on the dinner table. Culturally, in rural Ghana, women share the greater household management burden and hence are supposed to get food for the household (Pickbourn, 2011). Women's role in the study communities and Ghana more widely is socially defined. Culturally, females do all the household chores including cooking, fetching water, washing and cleaning. In some cases, female are also obliged to help their husbands on their farms for activities such as planting, weeding and harvesting. This sometimes leaves such female farmers limited time to work on their own farms. In addition, social organisation means that most women in the study communities and rural Ghana more widely are often responsible for providing educational expenses and clothing for their children (Pickbourn, 2011). To meet these household obligations women diversify their livelihoods into non-farm activities that require less skills and low capital outlay.

Despite this, and their critical role in ensuring household food security (Ibnouf, 2011; Quisumbing *et al.*, 1995), women in the study communities and Ghana more widely lack the "political capital that is often crucial in taking decisions regarding assets management for profitable investments in non-farm activities" (Yaro, 2006, p. 149). For instance, women in many rural farming communities have unequal access to resources including land and credit that will enable them to actively engage in non-farm livelihood opportunities (Denton, 2002). Generally, in Ghana women have difficulties in accessing credit because of a lack of collateral. Even in cases where women may have physical assets as collateral for bank credit, these assets are usually registered in their husband's name or joint registration, making it difficult to use such assets for credit without the expressed consent of their husband. This is due to unequal power relations between women and men in such communities, where there are power imbalances against women, which further exacerbates their vulnerability to climate variability (Kakota *et al.*, 2011; Glazerbrook, 2011). Although women are central to environmental management and sustainable development, they have often been neglected or under-represented in decision-making relating to adaptation to climate change and variability (Denton, 2002).

Livelihood diversification may also be used by households to efficiently utilise their factors of production, especially labour (Paavola, 2008). For instance, during questionnaire surveys and focus group discussions, farmers in the vulnerable communities reported working as causal labourers and undertaking other menial jobs in southern Ghana, especially in the Ashanti and Greater Accra regions, where environmental conditions and job opportunities are better. These farmers depend predominantly on rain-fed agriculture for their livelihoods and shortening of the growing period linked to increased drought has resulted in a limited period (June – October/November) during which these farmers could cultivate their lands. Hence, one of the more lucrative options is to explore other livelihoods opportunities including, but not limited to, selling labour.

The findings on the application and sharing of traditional knowledge in mitigating the impacts of climate variability, in relation to sharing of indigenous knowledge and social networks, are consistent with findings from other studies (Gyampoh *et al.*, 2009; Orlove *et al.*, 2010; Speranza *et al.*, 2010). For instance, Orlove *et al.* (2010) observed that farmers in southern Uganda use information on indigenous climate knowledge including particular phases of the moon as indicators of impending rainfall to plan their agricultural operations. Slegers (2010) reported that farmers in Central Tanzania were using signs such as stars and cloud watching as indicators of rainfall patterns. Indeed, this knowledge base represents a form of social capital which is shared among the members of the farming communities and can add value to climate change studies when properly integrated. This, therefore, means that this knowledge base should be considered and integrated with scientific climate knowledge in the design and implementation of appropriate climate adaptation policy in these regions as widely called for across the climate and development policy literature (e.g. Nyong *et al.*, 2007; Orlove *et al.*, 2010; Stringer *et al.*, 2009; Newton *et al.*, 2005).

It is significant to emphasise that most of the adaptation measures highlighted above are used by households in Ghana and SSA more widely as risk spreading measures to reduce the negative impacts of climate variability, but that they fail to take advantage of the opportunities presented in relatively good farming seasons (Cooper *et al.*, 2008). Such measures are more of coping strategies (rather than adaptations) that reduce present vulnerabilities without necessarily accounting for future climate changes. In this regard, for adaptation strategies to be effective and successful, they should reduce present and future vulnerabilities to climate change as well as increasing resilience (Huq *et al.*, 2004; Van Aalst *et al.*, 2008). Climate adaptation strategies should seek to maximise the potential benefits that can be derived from a more resilient society (Mitchell and Maxwell, 2010) and be compatible with national developmental agenda (see Chapter 8 for more on this).

6.7 Conclusions and policy recommendations

This chapter has critically evaluated the main coping and adaptation strategies used by households in the study communities to manage the adverse impacts of climate variability on their livelihoods activities (i.e. agriculture). This was done in the light of perceived changes by the households in relation to decreased rainfall and delayed onset of the rains for the farming season as well as increased temperature patterns compared with the 1960s and 1970s. The results have shown that households in the study communities employ a host of different on-farm and off-farm adaptation strategies.

On-farm adaptation strategies include changing the timing of planting, diversification of crops, planting early maturing varieties, planting drought-tolerant crops and using irrigation systems, where possible. Key off-farm adaptation strategies identified include relying on social networks, temporary migration, changing diets, reducing food consumption, and livelihood diversification. The chapter has shown that households employ coping strategies that are mostly linked to livelihood diversification. With regard to livelihood diversification, this chapter also presented empirical evidence that suggests that farming households in the study communities and Ghana more widely engaged in non-farm activities such as petty trading, selling livestock, charcoal production, working as forest assistants, food vendors, and shea nuts gathering to cope with climate variability.

Further, the results indicated that a household's choice of a particular climate adaptation strategy may be partly influenced by different socioeconomic factors including gender, age, educational level, perceived wealth and land tenure system as well as agro-ecological setting. Policy makers need to carefully consider these socioeconomic factors in the design and implementation of climate change adaptation policy in the study regions.

Building on previous studies on climate adaptation in SSA (e.g. Tachie-Obeng *et al.*, 2012; Bryan *et al.*, 2013), this chapter contributes to scientific debates on livelihood resilience at the household by enhancing our understanding of how small-scale farmers in the study communities and more widely are coping with the challenges posed by climate variability. The implication of the findings is that policy makers need to formulate targeted climate adaptation policies and programmes that are linked to enhancing livelihood diversification, fostering asset building, as well as encouraging households in different farming communities to share knowledge on climate adaptation, building from the positive actions that are already been taken to manage climate change.

As highlighted in Section 6.2, households in the study communities, like many other SSA communities, are confronted with multiple climatic and non-climatic stresses including drought and lack of infrastructural development, and it is therefore difficult to isolate climate adaptation from other non-climate adaptations. Although adaptation may be prompted by climate events such as droughts and floods, it should be acknowledged that these adaptation strategies are taken in response to the complex interplay of both climatic and non-climatic conditions including political, economic and socio-environmental changes (Mertz *et al.*, 2010). Hence, it is recommended that feedbacks and drivers from these non-climate factors should be considered in adaptation policy and implementation in order to increase policy effectiveness.

CHAPTER 7

BARRIERS TO CLIMATE VARIABILITY ADAPTATION: INSIGHTS FROM SMALL-SCALE FARMERS IN GHANA

Summary

This chapter identifies and evaluates the main barriers to climate change adaptation by households in the two study communities of rural Ghana. The results show that the main barriers include a lack of financial resources, poor access to information on climate adaptation, complex land tenure systems, and social-cultural factors. Furthermore, the lack of farm implements and machinery, lack of ready markets and limited access and high cost of improved varieties of crops are serious constraints to effective implementation of appropriate climate adaptation strategies by households. By identifying barriers to climate adaptation, this chapter provides an empirical understanding of the challenges confronting small-scale farmers in their attempt to implement adaptation and coping strategies to reduce their vulnerability to the impacts of climate variability.

7.1 Introduction

Understanding why and how different coping and adaptation strategies are used does not fully capture the interaction between climate variability and food production systems. To better understand the vulnerability of agriculture-dependent communities to climate variability requires exploration of the barriers that constrain the implementation of adaptation strategies. The identification and evaluation of barriers to climate change adaptation measures by farmers is an aspect of adaptive research that has been less researched (see Howden *et al.*, 2007; Nielsen and Reenberg, 2010a). This chapter aims to identify and evaluate the main barriers to the implementation of adaptation strategies by households at the local-level, providing a broader understanding of the extent of vulnerability of farming households to climate variability. This will help to provide improved guidance on appropriate interventions to enhance the resilience of agriculture-dependent communities. Barriers to climate change adaptation are defined as obstacles that have the potential to reduce the effectiveness of adaptation strategies but can be "overcome with concerted effort, creative management, change of thinking, prioritisation, and related shifts in resources, land uses, institutions etc" (Moser and Ekstrom, 2010, p. 22027).

7.2 Climate adaptation barriers identified in study communities

Table 7.1 presents the main climate adaptation barriers cited by households in both resilient and vulnerable farming communities during qualitative interviews where respondents were asked: *what things prevent the implementation of a particular adaptation strategy by farmers?*

The most commonly identified climate barrier was the lack of financial resources. About 92% (*n* = 248) of households sampled in both the resilient and vulnerable communities cited lack of financial resources as a serious barrier to climate adaptation (Table 7.1). Almost half (49%, *n* = 132) of the respondents from both the resilient and vulnerable communities indicated high cost of improved varieties of crops as a barrier. About 40% (*n* = 108) also perceived that poor access to climate information and lack of institutional capacity served as barriers. Another 31% and 29% of the respondents identified complex tenure systems and lack of farm implements respectively. Other climate adaptation barriers that were identified include social-cultural barriers (21%; *n* = 58) and a lack of ready markets (23%; *n* = 63) (Table 7.1). Table 7.1 also shows the specific adaptation strategies that were identified by households during the questionnaire survey that may be affected by the barriers identified by farmers. It should be stressed that a particular barrier could influence the effective implementation of more than one specific adaptation strategy. Table 7.1 shows that not only were financial barriers mentioned by the majority (92%) of households, but also that this underpins most of the adaptation strategies identified in Chapter 6.

As already mentioned in Chapter 6, in dryland farming systems in SSA, decisions on climate adaptations are taken in the light of other non-climatic stressors including accelerated population pressure, lack of markets and adverse economic development (Nielsen and Reenberg, 2010b; Mertz *et al.*, 2010). Barriers described in this chapter may not be specific to climate adaptation but may encompass other non-climatic factors and agricultural development more broadly (Mertz *et al.*, 2010). It is significant to emphasise that climate change and variability (particularly drought) will add an extra burden to farmers in dryland farming systems in Africa (UNDP, 2007), and therefore the ability to withstand these changes is crucial to the livelihoods of most farmers in this region. Each of the barriers identified above is unpacked in further detail in the following sections.

7.3 Lack of financial resources

The importance of financial resources in climate change adaptation cannot be overemphasised (Deressa *et al.*, 2009; Butt *et al.*, 2006). Lack of financial resources constitutes one of the greatest challenges to the effective implementation of climate adaptation strategies by households in the study communities. The results show that 92% (*n* = 248) of households – consisting of 86% and 97% in the resilient and vulnerable communities respectively – reported a lack of financial resources as a barrier to the successful implementation of climate adaptation strategies. Households in the resilient communities reported unavailability of credit facilities to purchase farm inputs such as fertilizers, farm implements and pay labourers. Most households in the resilient communities practise commercial monoculture that requires high capital outlay in terms of land preparation, labour and farm inputs. Describing the challenges posed by the lack of financial resources in climate adaptation, a farmer remarked:

> "*We use lots of fertilizers in our farming activities and these are very expensive for most farmers in this village but accessing credit to buy fertilizers and other farm inputs is extremely difficult. When I was growing up in this village in the 1960s my parents did not need to add any fertilizers to their crops, they were not also using tractors for their farming activities. This made farming relatively easier in terms of finances. These days if you do not apply fertilisers to your crops, you will not get enough yield to feed your own family. Farming has become capital intensive but getting access to credit is one of the difficulties confronting farmers"* [Focus group participant, Nyamebekyere, July, 2010].

Table 7.1: Proportion of households who cited particular barrier to climate adaptation

Specific barrier to adaptation	Number of respondents (n = 270)	Percent of respondents*	Examples of specific adaptation strategies influenced
Lack of financial resources	248	92	Planting trees, planting improved varieties of crops, diversification of livelihoods activities, changing diets
Poor access to climate information and institutional support	108	40	Changing the timing of planting, planting early maturing varieties.
Complex land tenure systems and gender issues	84	31	Planting trees, crop rotation.
Social-cultural barriers	58	21	Temporary migration, changing the timing of planting.
Lack of ready markets	63	23	Planting drought-tolerant crops, diversification of livelihoods and crops diversification.
High cost of and limited access to improved crop varieties	132	49	Planting early maturing varieties, planting drought tolerant crops.
Lack of farm implements and machinery	78	29	Planting early maturing varieties, changing the timing of planning.

*Most households are confronted with a range of barriers and that explains why the total exceeds 100%.

Though linked broadly to agricultural development, lack of financial resources in poor marginalised communities could exacerbate the likely adverse impacts of projected climate change on the livelihoods of these households. For instance, during FGDs, households in the resilient communities recounted the difficulties in accessing credit facilities from banks for farming activities. The farmers claimed that the banks are not interested in giving out loans to farmers for agricultural activities because of the fear that farmers may not be able to pay back any loans, due to the high-risk nature of rain-fed agriculture. Emphasising this, a key informant at Aframso noted:

> "*The banks demand collateral in the form of land title registration and ownership of assets such as building but most farmers in this community cannot provide such collateral, making it extremely difficult to access credit to implement adaptation strategies* [Female farmer, Aframso, August, 2010].

Key informants in the vulnerable communities claimed that households were unable to contract loans partly due to the inability of most of them to provide appropriate collateral to the banks. This is because most of them defaulted in the repayment of the loans they contracted from the banks in the past. Households also admitted that one major reason why they were not able to pay back bank loans is that most often the loans were given at the wrong time, sometimes after the main farming season had ended. The following response from a farmer detailed the extent of the problem:

> *"The processes involved in loan applications are cumbersome. Even when the loans are granted to farmers, the loans usually come very late sometimes after the main farming season has ended and the monies are used for other purposes so it becomes difficult to get money to pay back and the non-payment has resulted in the banks chasing some of the farmers and life has become unbearable."* [Male farmer, Key informant, Vea, September, 2010].

The above observations are linked to seasonal calendars in these communities. For instance, a seasonal calendar constructed with farmers during the FGDs suggests that households in the resilient communities plant their crops in March and April (Table 7.2) whilst those in the vulnerable communities plant their crops in late May and early

June (Table 7.3). This means that they need credit to buy planting materials and other farm inputs at these periods to be able to take advantage of the first rains. This is critical because when farmers fail to plant at the right time, crops will meet seasonal drought during the most critical stages of their growth. Hence, by not being able to access loans at the right time, households will encounter difficulties preparing the land and purchasing appropriate farm inputs for the start of the farming season. This could potentially make them fail to meet key timelines for certain farming activities that could increase their vulnerability to seasonal drought.

Indeed, interviews with officials of banks and microfinance organisations operating at the study communities confirmed the views expressed by farmers. When asked why banks and microfinance institutions were reluctant to grant loans to farmers, an official of a microfinance institution providing credit in the form of loans to small-scale businesses in the study communities remarked:

> "*Rain-fed crop farming is extremely risky. The rains are not consistent and farmers in these communities depend entirely on rainfall for their farming activities making it a risky business. Hence, extending credit for rain-fed farming activities is quite risky. You are never sure whether farmers will get enough rainfall for their crops"* [Bank Official, Ejura, August, 2011].

This has serious implications for climate adaptation and agricultural development more broadly. Given the climate projections outlined in Section 4.4 of Chapter 4, the risks presented by climate change to the livelihoods of these households are set to increase, yet the mechanisms needed to reduce this risk are not fully supported. This could potentially further exacerbate risks associated with climate change and variability.

Table 7.2: Seasonal calendar constructed with farmers in the resilient communities during FGDs based on their observation since 2000

		Jan	Feb	Mar	Apr	May	Jun[21]	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation				↔	↔	↔	↔ ★	↔	↔	↔	↔	↔	↔
Farming activities	Land preparation[22]		↔	↔				↔	↔				
	Planting[23]			↔	↔			↔	↔				
	Fertilizer application				↔	↔							
	Harvesting						↔	↔	↔		↔	↔	
No farming activities		↔											↔
Credit needed			★					★					

Table 7.3: Seasonal calendar constructed with farmers in the vulnerable communities during FGDs based on their observations since 2000

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation						↔	↔	↔	↔ ★	↔	↔		
Farming activities	Land preparation				↔	↔	↔						
	Planting					↔	↔	↔					
	Fertilizer application						↔	↔					
	Harvesting[24]							↔	↔	↔	↔		
No farming activities		↔	↔	↔	↔	↔						↔	↔
Credit needed						★							

NB: the star means when rainfall is heaviest and when credit is most needed by farmers to implement climate adaptation strategies

[21] According to FGDs in the resilient communities, the heaviest rain is in June/July whilst the month of August records the heaviest rainfall in the vulnerable communities.
[22] Unlike the vulnerable communities, farmers at the resilient communities have two rainfall seasons–minor and major–and therefore two farming seasons (Table 3.2)
[23] Quote: *"I now plant maize in March as soon as the first rains come"* [Male farmer, Babaso, 2010].
[24] Early millet, guinea corn and late millet are harvested in July, September/October and October respectively.

Households within the vulnerable communities were concerned about the unavailability of credit facilities to enable them to diversify their livelihood activities into alternative non-farm jobs that are less dependent on rainfall. A key informant explained that households are being encouraged to diversify their livelihoods into non-farm jobs. However, most do not have money to engage in those non-farm activities that are less likely to be impacted by the changing weather patterns. According to the key informant, improved varieties of crops are very costly but farmers in the communities have no funds to purchase them for planting so they continue to use the traditional varieties that may be less drought-tolerant. This suggests that the lack of financial resources could potentially limit the adaptation options available to the small-scale farmers. These findings are similar to those of Bryan *et al.* (2009) that suggest that financial barriers due to lack of credit facilities is one of the most important obstacles hindering the implementation of appropriate climate adaptation strategies by farmers in Ethiopia. Generally, small-scale farmers in the study communities are considered poor. For instance, data from the Ghana Statistical Service indicate that an estimated 90% and 28% of the people in the vulnerable and resilient regions respectively live on less than $1.00 per day and are therefore considered poor (GSS, 2000). Poor households have limited amount of capital assets that may be needed to reduce the impacts of climate variability on their livelihoods and thus may be least prepared to deal with climate related shocks (see Dasgupta and Baschieri, 2010).

It is significant to note that there were marked differences between typical households and outlier households within the vulnerable communities regarding financial barrier. For instance, the 3% of households in the vulnerable communities that did not report financial barrier as a key barrier to climate adaptation were all outlier households (i.e. households demonstrating low vulnerability – Chapter 5). Importantly, it could be argued that financial barriers may be a reflection of the socioeconomic condition of the household. This may also be related to social status of households within the study communities. This is because household heads who occupy social and political positions within such communities could use their political influences as well as their social networks to access credit and other forms of financial capital that could reduce their vulnerability to drought-related food insecurity. Again, within the vulnerable communities, farmers with good education (mostly the outlier households) and have non-farm income jobs could invest some of their income from such jobs into climate adaptation measures. The next section (Section 7.4) explores how poor access to climate information could also hinder attempts to cope with climate variability in the study area.

7.4 Poor access to information on adaptation and institutional support

Access to information on climate change is a very powerful tool that can be used to enhance the adoption and implementation of coping and adaptation strategies by households in SSA (Roncoli *et al.*, 2002). This is particularly important for Africa (IPCC, 2007) and Ghana in particular, where there are few climate projections due to lack of appropriate climate data. Successful implementation of climate change adaptation strategies requires that farmers do not only have sufficient knowledge about the available options, but also have adequate capability to assess the available options so as to make informed decisions on the best adaptation strategies (Lee, 2007). About 40% (*n* = 108) of the households interviewed cited poor access to information on climate adaptation as a serious barrier. There were significant similarities between farming households in the resilient and vulnerable communities. During FGDs, farmers in both study regions reported that the lack of information on the onset and distribution of the rains during the farming season was a serious challenge to the implementation of appropriate adaptation strategies including changing timing of planting; planting early maturing varieties of crops (see Case 5 in Table 5.4). Explaining this, a key informant at Vea gave a characteristic response as:

> *"We do not have access to reliable information on the weather in terms of when the rains will start. We rely on our traditional knowledge but this is becoming extremely unreliable with the climate becoming more erratic. We lack reliable information on the distribution of rainfall during the farming season, making it difficult for farmers to plan their farming activities"* [Male farmer, Vea, 2010].

Poor access to information on climate is further hampered by the unavailability of electricity in the farming communities (especially those in the vulnerable region), making it difficult for farmers to access climate information, even when weather forecasts are broadcast by the Ghana Meteorological Agency. Although the general impression was that households lack access to climate information, a critical examination of the results suggests that there were marked differences between resilient and vulnerable households. Whilst 65% (n = 88) of households in the resilient communities reported poor access to climate information as a barrier, it was noted by a staggering 84% (n = 113) of the households in the vulnerable communities. This disparity could be explained by the differences in the level of education and access to livelihood assets between households in the resilient and vulnerable communities (Table 5.3). Lack of formal education coupled with the lack of physical assets such as television and radios in most of these households made it difficult to access such information.

In terms of gender, the results suggest that more female-headed households (82%) in both the resilient and vulnerable communities indicated poor access to climate information compared to 66% of male-headed households. Education could influence accessibility to climate information through the adoption of improved climate adaptation strategies as well agricultural technology more broadly (Innes, 2010; Lin, 1991). The lack of formal education, in the study communities according to extension officers, sometimes makes it difficult for most farmers to understand simple instructions on insecticide and herbicide applications. In this regard, it is essential that information on climate adaptation strategies are communicated in local languages and efforts should be made to employ words that are familiar in describing such strategies (e.g. Van Aalst *et al.*, 2008). To this effect, Lata and Nunn (2011) have argued that the ownership of climate change adaptation strategies by households and the community in general is crucial for the successful implementation of such strategies. It is therefore important that the local indigenous knowledge of climate adaptation used by the households be synthesised with scientific climate information to help households own and implement the necessary adaptation and coping strategies.

It was also discovered during transect walks and household surveys with farmers that lack of climate information is closely related to lack of institutional capacity. Institutions are defined as the “social cement which link stakeholders to access to capital of different kinds to the means of exercising power and so define the gateways which they pass on the route to positive or negative adaptations” (Davies, 1996, p. 24).

Institutions play a crucial role in enhancing the capacity of local communities to cope with climate variability and providing mechanisms that help to shape the social and individual interactions within the society (Agrawal and Perrin, 2009; Adger and Kelly, 1999). About 28% (*n* = 75) of respondents in both the resilient and vulnerable communities were unanimous in describing the lack of institutional support notably poor extension services as barrier.

Extension officers are supposed to link between the scientific community and farmers by facilitating the flow of scientific ways of farming, including the adoption of innovative ways of farming, to farmers. However, qualitative interviews suggest that poor extension services hamper the flow of information on climate adaptation to farmers. Households claimed that they do not get adequate information on early warning systems from the government, particularly regarding rainfall distribution during the farming season, and this makes them more vulnerable to intra-annual rainfall variability. Expert interviews with staff at the Ministry of Food and Agriculture at the district level revealed that the extension officer to farmer ratio is very high. For instance, in the vulnerable communities the extension officer to farmer ratio is about 1:1500 compared with the national average of about 1:1200. The ratio in the resilient communities is about 1:1216. This sometimes makes it practically impossible for the extension officers to attend to the needs of these farmers within a reasonable time period. The lack of climate adaptation information including weak institutional capacity coupled with the intra-annual rainfall variability and increased temperature will place food security in Ghana, like many other SSA countries, under considerable stress (Codjoe *et al.*, 2011)

7.5 Complex land tenure systems and gender issues

Secure land tenure is critical for investment in climate change adaptations. Land is a very important asset especially for agriculture-based livelihood activities. Though related broadly to agricultural development, secure land tenure was described by 31% (*n* = 84) of respondents from across the resilient and vulnerable communities as barrier to climate adaptation (Table 7.1). The results also suggest marked differences between the resilient and vulnerable households in relation to the percentage of respondents citing complex land tenure system and gender issues as a climate adaptation barrier.

For instance, the results revealed that whilst few respondents (24%; n = 32) in the resilient communities believed land tenure was hindering climate adaptation strategies (and agricultural development more widely), almost half of the respondents (46%; n = 62) in the vulnerable communities described the complex land tenure system as a serious obstacle.

The analysis revealed that gender of the head of the household may affect the perception of complex tenure system as a constraint to climate adaptation. For example, of the 46% households that cited the complex tenure system as barrier to climate adaptation in the vulnerable communities, only 22% were male-headed households, compared to a large majority of female-headed households (78%). Similar trends were observed at the resilient communities, where fewer male-headed households compared with female-headed households described complex tenure system as a barrier.

Qualitative interview data suggest that two groups of households – migrant households in the resilient communities (located in the south) and female-headed households in the vulnerable communities (located in the north) – may be disadvantaged by the land tenure system in the study communities. The results suggest that the majority of male-headed households in the resilient communities that claimed complex land tenure system constituted a barrier to climate adaptations were mainly migrant farmers who were renting their farm lands. Most of these migrant farmers have come from northern Ghana in search of better farming conditions.

The 1992 Constitution of the Republic of Ghana invests all land resources in the paramount chieftaincy (a stool in southern Ghana and or a skin in northern Ghana). As noted in Chapter 3 (Section 3.3), ownership of customary land differs remarkably across the different parts of the country. In southern Ghana (where the resilient communities are located, see Figure 3.5), both male and female members of a particular family (*abusua*) or clan can access and own land for farming and other economic activities. Members of a particular family (*abusua*) or community can acquire land for farming and other developmental ventures preceded with presentation of customary gifts to the traditional leader (Kasanga, 1997), who may be a chief (*odikro*) or the family head (*abusuapanyi*n). Non-community members (i.e. migrant farmers) have no communal rights to communal land and may acquire land for farming by entering into a contractual agreement with the chief (*odikro*) or the family head (*abusuapanyi*n) for a specific period of time (see Goldstein and Udry, 2008; Kasanga *et al.*, 1996).

Migrant households can access land through share cropping arrangements, popularly known as *abanu* where the migrant worker gets land and farm inputs such as seeds and fertilizers from a particular land owner and the crop yields are shared equally between the land owner (usually a native of the community) and the migrant worker. Migrant farmers can also rent farmlands and pay rent in the form of an agreed quantity of grain after harvest. Despite providing access to members of a particular family to carve out their livelihoods, the customary land tenure system may prohibit migrant households from planting trees that last longer than annual food crops. The planting of trees may be considered as a symbol of land ownership in these communities. This means that such migrant households may not be able to implement certain climate adaptation strategies such as agro-forestry, thus limiting the ability to control their own decision making and ability to enact climate adaptation strategies.

Poor soil fertility management and cropping practices that lead to low agricultural productivity in most parts of Africa have been partly attributed to a lack of land tenure security (Damnyag *et al.*, 2012; Adjei-Nsiah *et al.*, 2006). For instance, migrant farmers have often resorted to unsustainable cropping practices that tend to reduce soil fertility, partly due to tenure insecurity, and this sometimes creates mistrust between natives and migrant farmers (Adjei-Nsiah *et al.*, 2006). It is argued that farmers will have a strong incentive to invest in land improvement and conservation practices when they have better land rights (Deininger and Jin, 2006; Besley, 1995). However, singling out and drawing a direct causal effect between land tenure insecurity and a lack of investment in soil fertility that result in poor agricultural productivity in SSA has been contested (Bugri, 2008; Place and Otsuka, 2002). Low agricultural productivity in SSA may be attributed to non-tenurial factors such as inadequate and unreliable rainfall, bush burning, and a lack of finance (Place, 2009; Bugri, 2008).

Female-headed households, especially those in the vulnerable communities, were more concerned with lack of tenure security as a result of social-cultural discrimination against females regarding distribution and ownership of farm land. In northern Ghana[25] (where the vulnerable communities are located) there are complex land tenure systems. In such communities, it is the Tendana, who owns ‘alloidal’ rights to all lands in the community and therefore entitled, under the customary system, to grant usufruct rights to families and individuals within the community (Yaro, 2010). The Tendana is usually a patrilineal descendent of the original family that first settled in the community but occasionally, may be chosen by a soothsayer. As highlighted in Chapter 3 (Section 3.3), land inheritance in northern Ghana is through the male heir, and female right of usufruct is not recognised under the customary law[26] (Yaro, 2010). Women in the vulnerable communities can only access land through marriage or sometimes by borrowing or begging (Yaro, 2010). Should the man and woman be divorced, the woman would lose such land. Widows can access farmland only if they had male children with their husbands. The belief is the women marry out of the family and therefore should use part of their husband’s family land (Yaro, 2010). Unmarried women have limited access to land and those who may have access tend to be given the most unproductive farmlands.

The implication of this cultural discrimination against females relating to land ownership for food security and climate change vulnerability is explored in Chapter 5. The fact that female farmers have less tenure security is worrying as it has serious implications for climate adaptation, food security and agricultural development more widely in the study regions and Ghana in general. This is because women play a significant role in ensuring livelihood resilience at the household level. In spite of the important role in ensuring food security (Quisumbing *et al.*, 1995; Ibnouf, 2011), women have often been less represented in decision making on global climate change policy (Denton, 2002; Glazerbrook, 2011). Access and control over land resources are also greatly influenced by power relations within these farming communities such that the influential people who hold social power such as the chief (*odikro*), family head (*abusuapanyin*) and chief’s spokesman (*okyeame*) may have greater access and control over customary lands (see Goldstein and Udry, 2008).

[25] Northern Ghana refers to the three geographical and administrative regions – Northern, Upper East, and Upper West regions – that are located in the northern most part of Ghana and share similar geographical and socio-cultural characteristics.
[26] Migrant farmers in the north may also access land through various agreements including purchase. Generally, there are few migrant farmers in the north compared to the south because of unfavourable farming conditions in the north.

The commoditisation of land in the study area and Ghana more widely due to peri-urban development has added significant pressure to the tenure insecurity in the study communities. In addition, land grabbing for citrus and *Jatropha curcas* cultivation is becoming an obstacle to food security in Ghana in general, and in particular the three northern regions of Ghana, due to the dispossession of already marginalised farmers who are inadequately compensated to engage in other livelihood activities. What follows is an explanation of how social-cultural barriers, lack of markets and high cost of improved varieties could constrain climate adaptation strategies by households.

7.6 Social-cultural barriers to climate change adaptation

Social-cultural barriers relate to various processes including traditional beliefs, values and cultural systems and the local social institutions that govern these belief systems. Social barriers prevent farmers from "seeking the most appropriate forms of climate adaptation" (Jones, 2010, p. 2). Despite the attention given to adaptation in recent years at the international level, most literature tends to overlook how social and cultural forces could enhance or constrain climate adaptation (IPCC, 2007). Belief systems in the farming communities constitute one of the greatest barriers to the implementation of climate adaptation strategies by households. Strongly held belief and value systems and the worldviews of these farmers greatly influence the way they perceive climate change and thereby their subsequent adaptation strategies (Moser and Ekstrom, 2010; Preston and Stafford-Smith, 2009; Jones and Boyd, 2011). The results show that both male and female-headed households in resilient and vulnerable communities claimed that traditional beliefs and norms may serve as barriers to successful climate adaptations. Indeed, these farmers have inherited complex belief systems from their forefathers and these are strictly upheld and observed. Specific belief systems identified by the farmers as barriers were varied.

Figure 7.1 shows one such situation where farmers in Nyamebekyere believe that the two stones represent a male and female and that these stones are a '*couple'*. Key informants claimed that because of this, farmers are not allowed to go to their farms in this area (i.e. where the stones are located) on Fridays. This has implications for certain adaptation strategies such as changing the timing of planting. Even when it has rained and farmers want to plant the day after the rains, they cannot do that if it falls on a Friday. According to a key informant, the belief is that when one disobeys and goes to the farm on such days he/she is likely to have an "unpleasant experience" such as meeting a "dwarf". The key informant reported that in certain situations farmers who defy these traditions may be summoned by the chief of the village and require to slaughter sheep to pacify the gods (Chief of Nyamebekyere, pers. comm., August, 2011). According to the key informant, if such rituals are not performed, it could bring future hardships (including drought) to the local community. It is believed in this community that rainfall and droughts are events that are determined by such smaller gods.

Evidence in the literature suggests that providing people (including farmers) with scientifically sound information on climate change will not necessarily lead to the implementation of adaptation polices (Adger *et al.*, 2007; Jones, 2010). The belief and cultural systems of society play crucial role in the decision to take pragmatic measures to adapt to climate variability and change (Patt and Gwata, 2002; Nielsen and Reenberg, 2010a). For instance, cultural barriers prevented certain cultural groups in northern Burkina Faso from implementing certain livelihood strategies aimed at reducing their vulnerability to climate variability (Nielsen and Reenberg, 2010a). In this regard, the appreciation of the local context within which climate adaptation takes place is quite crucial (Ensor and Berger, 2009). Indeed, there is increasing demand for adaptation strategies that acknowledge local context such as belief systems and indigenous knowledge (e.g. Jennings and Magrath, 2009).

Belief systems also affect farmers' adoption of new innovations, especially those that are parallel to such strongly held cultural practices. It was discovered during the ecological surveys that some households in the study communities were not planting the early maturing varieties of maize. Some of the households related their non-planting of such varieties to their belief systems. Emphasising this, a farmer at Vea commented:

"We are simply used to the traditional varieties of crops. That is what our ancestors used to plant and left for us. We are compelled to continue with the tradition our forefathers left with us" [Female farmer, Vea, September, 2010].

Figure 7.1: Two stones believed to be “couples” by farmers at Nyamebekyere, Ghana

Transect walks in the communities with opinion leaders revealed further that cultural beliefs are deeply engrained. These beliefs pervade their everyday activities and are sometimes used to rationalise most of the things that happen to them in life. Hence, they attribute most of the things that happen in their lives to divinity, with the causes of climate change being no exception. Asked farmers the causes of climate variability and change in the communities, most of them mentioned divine will as one of the causes of the change. This phenomenon could pose a barrier to climate change adaptation because once farmers believe that climate change is due to divine will, they will be less inclined to implement actions to cope with it.

7.7 Lack of readily available markets

The lack of ready markets for households in the study area also serves as a serious barrier for the successful implementation of certain climate adaptation strategies including planting drought-tolerant crops as well as diversification of crops (see Table 7.1). Though linked more widely to agriculture development, some respondents (23%; n = 63) in both the resilient and vulnerable communities described the lack of readily available markets as hindering climate adaptation. For instance, qualitative interview data as well as agro-ecological surveys revealed that most of the households, especially those in the resilient communities, were planting drought tolerant crops such as cassava to cope with erratic rainfall patterns. However, during FGDs, households claimed that they had greater difficulties in marketing these crops compared with maize, which may be more susceptible to drought. About 39% (n = 53) of the respondents in the resilient communities cited lack of readily available market compared with fewer respondents (7%; n = 9) in the vulnerable communities. This difference could be explained by the fact that the majority of households in resilient communities practise large-scale commercial farming. The lack of ready markets as a barrier to climate adaptation is, perhaps, fully appreciated when it is related to the obligation of households to fulfil their credit repayments. If households are not able to get good markets for their produce, they will not be able to repay their loans and this will have serious implication for their ability to contract future loans to implement adaptation strategies.

During FGDs, farmers claimed that the market women determine the prices of their produce. Small-scale farmers in Ghana have a very weak position in marketing their farm produce as most of them sell their farm outputs soon after harvesting at very low prices (EPA, 2003). Describing the characteristic view of the farmers, a female farmer at Babaso gave this response:

> "*We do not have ready market for our farm produce. Most often it is the market women who determine how much they want to pay for our farm produce. They come and buy our produce very cheaply and make it difficult to repay our loans*" [Female farmer, focus group participant, Aframso, August, 2010].

Despite the low prices offered by these market women, farmers are also not able to resist the temptation not to sell their farm produce. Explaining this, a farmer remarked during a focus group discussion:

> *"Prices for maize by the market women may not be good. [In spite of this] you cannot refuse to sell your farm produce when your family needs money to sort some pressing family needs"* [Focus group participant, Aframso, August, 2010].

The lack of market is related to lack of appropriate storage facilities for farm produce in these farming communities. Indeed, the lack of storage facilities weakens the bargaining power of the small-scale holder when it comes to negotiating the prices of farm produce. This is because most of them cannot store their farm produce and therefore accept whatever price the market women decide to offer. In the vulnerable communities, the few households who had access to irrigation facilities to cultivate tomatoes during the dry season recounted the difficulties they were encountering in marketing their tomatoes. Households reported that they lack a market for their tomatoes. According to them, the tomato sellers from Kumasi and Accra prefer to go to Burkina Faso. Farmers indicated that these tomatoes sellers claim that tomatoes from Burkina Faso are durable.

Lack of market access is also related to poor physical infrastructure development such as road networks. During qualitative interviews, farmers claimed that market women find it difficult to come to such communities because of the bad road networks. Transect walks in the communities revealed that the physical infrastructure in the resilient communities was far better compared with that in the vulnerable farming communities. Households in the resilient communities have access to the Ejura market where they can sell their farm produce (see Figure 3.5). By contrast, households in the vulnerable communities have no viable markets apart from the Bolgatanga market. Indeed, harsh environmental conditions coupled with inherently poor soils (Oteng *et al.*, 1990) and a lack of access to markets as well as well-functioning financial institutions have contributed to food insecurity in the vulnerable communities (Whitehead, 2006).

7.8 High cost of and limited access to improved crop varieties

One of the main adaptation strategies that households employ to manage climate variability is the use of improved varieties of crops including drought resistant and early maturing varieties (see Chapter 6). However, the results of the household questionnaire survey revealed that about 49% (n = 132) of households sampled considered high cost and limited access to improved crop varieties as a major barrier to climate adaptation. This consists of 67% (n = 90) households in the resilient communities compared with about 31% (n = 42) in the vulnerable communities. This is also related to lack of financial resources. This is because if there are credit facilities available to households, they can afford these improved varieties.

As part of the household survey, farmers were asked about the nature of obstacles regarding improved varieties of crops. They indicated that they either have difficulties in accessing such varieties or when they are available the price may be prohibitive, which sometimes compels many of them to use the traditional varieties. Both female and male-headed households in the vulnerable communities expressed similar concerns regarding these difficulties. Whilst most of the households in the resilient communities cited high cost of the improved varieties of crops, those in the vulnerable communities were concerned with both access to, and high cost of these varieties. Qualitative interviews with farmers in the vulnerable communities revealed that most households were using their stored seeds or obtaining seeds from families and friends for planting. Households claimed that they store part of their farm produce for sowing during the following farming season. However, what is not clear was whether those households who claimed to use their own seeds were indeed using improved varieties. This is because most of the improved varieties are hybrid seeds that must be obtained from seed companies or extension officers. Unlike traditional varieties, farmers cannot use their own seeds and have to buy the hybrid seeds from the seed companies every year.

7.9 Lack of farm implements and machinery

Though related to agricultural development more widely, the lack of farm implements and machinery was identified by some households (29%; n = 78) to constitute a major obstacle to the successful implementation of climate adaptation strategies such as planting early maturing varieties of crops. The results show that the majority of respondents that described lack of farm implements as a barrier were from the resilient communities. This is because, as noted earlier, most households in the resilient communities engaged in large scale commercial mechanised farming. Respondents explained that most of them do not have their own tractors and ploughs and therefore have to hire these implements. However, households claimed that sometimes when the rains have finally come they may have to wait for several weeks before they can have their farm lands ploughed for planting. This may interfere with the timing in planting certain crops. For instance, seasonal calendars constructed during FGD with farmers in the vulnerable communities (Table 7.3) suggest that if farmers fail to plant their crops by the second week in July, they are likely to have drought during the most critical period of crop growth. Similar trends were observed in the resilient communities, where seasonal calendars (Table 7.2) show that farmers need to plant by March to take advantage of the early rains to avoid seasonal drought.

7.10 Conclusions

Climate change and variability (particularly drought) continues to adversely impact on the livelihoods of many households, especially agriculture-dependent households in dryland SSA (IPCC, 2007), presenting serious challenges to the attainment of the Millennium Development Goal of eradicating poverty and hunger. Hence, there is a need for urgent, practical adaptation strategies to deal with the threat posed by climate change and variability. In their attempt to implement appropriate strategies to cope with and adapt to climate variability, rural households in the study communities and SSA more widely have been found to be confronted with a number of barriers that revolve around a range of climatic and non-climatic factors.

Some of the main barriers include a lack of financial resources, poor access to information on climate adaptation and institutional support, complex land tenure systems, and social-cultural barriers and gender issues. Others include limited access to improved varieties, lack of farm implements and lack of markets. With regard to land tenure, findings in this chapter demonstrate that land tenure is importantly involved in disposing two groups of farmers – migrant farmers in the resilient communities (located in the south) and female farmers in the vulnerable communities (located in the north) – as vulnerable by limiting the access of these two groups of households to land. It is significant to stress that until these barriers are focused on and overcome with appropriate solutions, Ghana government’s efforts and policies aimed at reducing the vulnerability of agriculture-dependent households and communities to climate change and variability may not achieve the desired results.

By highlighting the barriers to climate adaptation, this chapter has contributed to this thesis by providing a detailed and nuanced understanding of the main barriers that need to be addressed for climate adaptation by households in the study communities to be effective. This is necessary to inform policy design and implementation in order to reduce the overall vulnerability of rural communities dependent on rain-fed agriculture. Furthermore, this chapter contributes to the academic discourse on climate change adaptation by providing empirical evidence to deepen our understanding of the barriers that confront small-scale farmers in their attempt to implement appropriate adaptation and coping strategies to manage the impacts of climate change and variability.

CHAPTER 8

POLICY ANALYSIS AND RECOMMENDATIONS

8.1 Introduction

Building on the findings of the previous three chapters, this chapter identifies policy recommendations that aim to reduce the vulnerability of food production systems and livelihoods to climate variability. To achieve this, the chapter has the following specific objectives, to:

1. Highlight the key stakeholders in the implementation of the UNFCCC and UNCCD at the national level in Ghana. The UNFCCC and UNCCD are explored because these two international treaties seek to address the challenges posed by climate change and desertification (drought), which could negatively impact on food security in Ghana;
2. Analyse the various policies aiming to tackle climate change and desertification as well as food security and examine the complementarity between these policies;
3. Identify policy recommendations based on the policy analysis and the findings from this research that can be implemented to reduce the vulnerability of food production systems and rural livelihoods to climate variability in Ghana and SSA more widely.

The results of the content analysis of the key policy documents, together with the findings of this study (particularly Chapters 4–7), were presented to experts and stakeholders in a series of expert interviews in 2011 to elicit possible policy recommendations from this thesis (see Chapter 3 for details on the policy analysis and expert interviews). Currently, the Ghana government is developing a National Climate Change Policy Framework (NCCPF) and finalising work on a National Climate Change Adaptation Strategy (NCCAS). Findings from this chapter in the form of policy briefing will input into these national documents aimed at buffering the Ghanaian economy against the adverse impacts of climate change and variability.

8.2 Stakeholders for the implementation of the UNFCCC and UNCCD in Ghana

The United Nations Framework Convention on Climate Change (UNFCCC) is the primary international tool for addressing the problem of climate change (Klein *et al.*, 2007). Ghana signed the UNFCCC in 1992 and ratified it in September, 1995 (EPA, 2001). With regard to drought and desertification, the major international tool for addressing desertification is the United Nations Convention to Combat Desertification (UNCCD) (Stringer *et al.*, 2007b). Ghana signed the UNCCD in October, 1994 and ratified it in December 1996. The ratification of these two international conventions provided a mandate for the government of Ghana to initiate programmes and policies to address the problems relating to climate change and desertification.

The Ministry of Environment, Science and Technology (MEST) is the main government institution mandated to formulate appropriate policies aimed at tackling climate change and desertification. The MEST collaborates with other ministries and agencies to ensure that programmes and policies are implemented. Prominent amongst these are the Ministry of Finance and Economic Planning (MoFEP), Ministry of Food and Agriculture (MoFA), and the Environmental Protection Agency (EPA). The EPA, one of the agencies under MEST, was established by Act 470 in 1994 and is mandated to ensure the implementation of government policies relating to the environment. Hence, the national focal points for both the UNFCCC and UNCCD are located within the EPA (see Figure 8.1).

8.3 Analysis of relevant policy documents

This section presents an analysis of the main policies governing climate change, desertification and food production in Ghana. The following policy documents relating to climate change, desertification and agricultural production in Ghana were analysed:

1. Initial National Communication (INC)
2. The National Climate Change Adaptation Strategy (NCCAS),
3. National Action Programme to combat desertification and drought (NAP),
4. The Food and Agriculture Sector Development Policy Phase II (FASDEP).
5. National Land Policy.

The selection of these policies was based on expert guidance and thematic analysis of different sector policy documents that mentioned or highlighted food security, climate change adaptation, drought and desertification. Given that this thesis seeks to determine the extent of vulnerability of food production and livelihood systems to climate variability in order to identify policy recommendations, these policies are relevant as together they provide a comprehensive picture of the programmes and practices that have been formulated and implemented. Table 8.1 outlines the key themes covered in the INC (NCCAS), NAP and FASDEP in relation to food production systems and climate variability, as identified through the content analysis of policy documents.

Table 8.1: Key themes relating to climate change and food security covered in Ghana's INC, NAP and FASDEP that are relevant to enhancing the resilience of food production

Key themes relating to agriculture and climate change	NAP	INC (NCCAS)	FASDEP
Increased food production			X
Development and promotion of drought-tolerant crops	X		
Increasing access to farm inputs	X		X
Increasing access to market	X		X
Mainstreaming national development and environmental change		X	
Sustainable land use management practices	X	X	X
Improved agricultural mechanisation			X
Management of vegetative cover	X		
Agricultural diversification	X	X	X
Livelihood diversification into non-farm enterprises		X	
Improved institutional coordination			X
Training and institutional capacity building	X	X	X
Sustainable forest management	X	X	
Improving land tenure arrangements			X
Increased irrigation and water resources management	X	X	X
Development of early warning systems	X	X	X
Applying science and technology to agriculture			X
Education and public awareness	X	X	
Promotion of block farming	X		

FASDEP = Food & Agriculture Sector Development Policy, INC = Initial National Communication, NAP = National Action Programme to combat desertification, NCCAS = National climate change adaptation strategy

8.3.1 Initial national communication and the national climate change adaptation strategy

In line with the requirements of the UNFCCC, Ghana submitted its Initial National Communication (INC) and the Second National Communication[27] to the Conference of Parties (CoP) to the UNFCCC in 2000 and 2011 respectively. Under the UNFCCC, Ghana is obliged to implement appropriate programmes to ensure the integration of climate change issues into national development planning. Ghana's economy is heavily dependent on rain-fed agriculture (see Chapter 1), with almost 57% of the population depending on rain-fed agriculture for their livelihoods (ISSER, 2003). Hence, there is the need to develop appropriate strategies to mitigate the effects of climate variability (including drought) on livelihoods.

The National Climate Change Adaptation Strategy (NCCAS), which is still being finalised, primarily aims to identify ways to increase the country's resilience to reduce the adverse impacts of climate variability. The NCCAS adopts a cross-sectoral and participatory approach in highlighting the major sectors of the Ghanaian economy (energy, agriculture, health, water, land use, and development) that are particularly vulnerable to climate change (EPA, 2008). The NCCAS is the product of various vulnerability and adaptation assessments that have been conducted since 2006 by multiple stakeholders including experts from the country's national universities and other research institutes, governmental ministries and agencies as well as NGOs under the Netherlands Climate Change Assistance Programme (EPA, 2008). Hence, the NCCAS identifies adaptation strategies for various sectors. These strategies are then prioritised based on the *Akropong's Approach*[28] (Kemp-Benedict and Agyemang-Bonsu, 2008) to highlight 10 key crosscutting adaptation programmes[29]. For

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[27] At the time of conducting the policy analysis the Second National Communication was not finalised.

[28] This is a cross-sectorial impact planning and methodological tool that is used to prioritise the main strategies that were identified under each sector of the NCCAS. The approach uses qualitative and quantitative analytical tools such as multi-criteria analysis to bring diverse adaptation options under various sectors into manageable units (see Kemp-Benedict and Agyemang-Bonsu, 2008).

[29]These 10 adaptation programmes synthesised from the various adaptation strategies highlighted for the various sectors include: (1) improving identification of early warning systems; (2) improving land use management; (3) enhancing adaptation through research and awareness creation; (4) managing water resource to enhance livelihoods; (5) implementing appropriate environmental sanitation systems and strategies; (6) encouraging agricultural diversifications & socioeconomic development; (7) improving access to healthcare to reduce the impacts of climate change on human health; (8) enhancing management of fisheries resources to improve livelihoods; (9) developing measures to adapt national energy supply to climate change; and (10) minimising the effects of climate variability on the poor and the vulnerable.

agriculture, the NCCAS identifies programmes including the promotion of alternative livelihoods, enhancing early warning systems as well as encouraging agricultural diversification and improved land use management practices (Table 8.1).

With regard to implementation, the MEST is mandated to have a supervisory role. At the national level, the MEST is assisted in its supervisory role by the National Climate Change Committee that is represented by parliamentarians, experts from governmental ministries, research institutions and civil society organisations (GoG, 2011). The MEST exercises its supervisory role over the various ministries and departments as well as agencies who are supposed to implement the programmes and practices identified in the NCCAS (see Figure 8.1).

8.3.2 National action programme to combat desertification and drought

Desertification is defined as “land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities” (UNCCD, 1994, p. 4). The UNCCD (1994, p. 7-8) defines land degradation as “a reduction or loss, … of biological or economic productivity and complexity of rain-fed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes including processes arising from human activities and habitation patterns such as soil erosion caused by wind and/or water, deterioration of the physical, chemical and biological or economic properties of soil and long term loss of natural vegetation.” These definitions show that desertification can only occur in arid, semi-arid and sub-humid areas, whilst land degradation could occur in anywhere in the world.

In Ghana, land degradation and desertification present one of the greatest challenges to food production through loss of vegetative cover, soil erosion, reduced soil productivity that leads to reduced crop yields (EPA, 2003). Hence, desertification affects the livelihoods of many land users (EPA, 2003). An estimated 35% of the total land area in Ghana is prone to desertification (EPA, 2003).

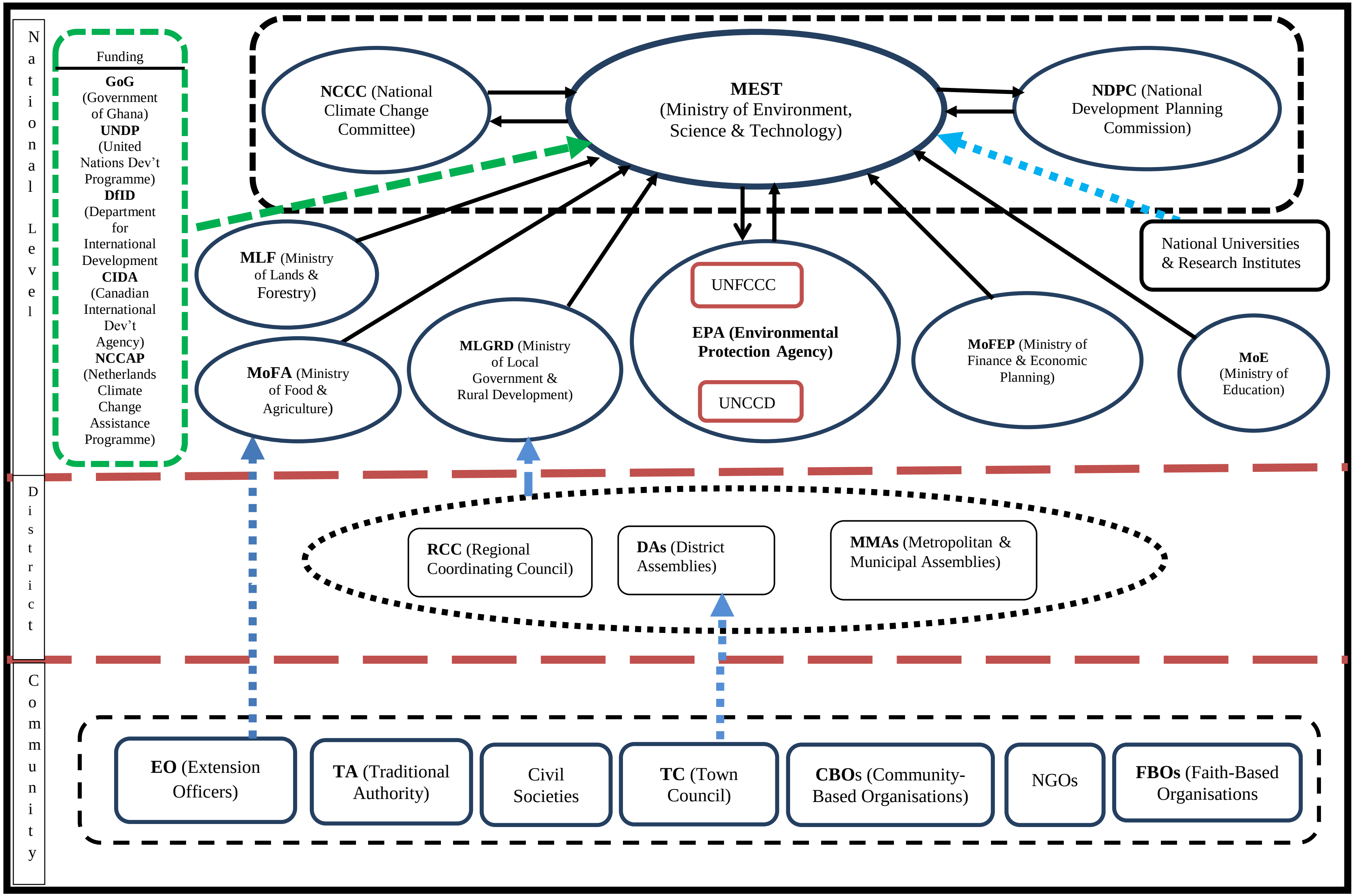

Figure 8.1: Institutional structure for climate change adaptation in Ghana

Drought related crop failure has been well documented (MoFA, 2007). As a signatory to the UNCCD and a country that considers itself affected by desertification, Ghana was obliged to prepare a National Action Plan (NAP) to combat desertification and mitigate the adverse effects of drought. The EPA, which was mandated with the responsibility of preparing this action plan, developed a national action plan in 2002 that was submitted to the UNCCD secretariat. The objective of the NAP is to "emphasize environmentally sound and sustainable integrated local development programmes for drought-prone semi-arid and arid areas, based on participatory mechanisms, an integration of strategies for poverty alleviation and other sector programmes including forestry, agriculture, health, industry and water supply into efforts to combat the effects of drought" (EPA, 2003, p. 5).

The UNCCD seeks to promote and encourage the use of participatory approaches to combat desertification (UN, 1994) despite the challenges this brings (Stringer *et al.*, 2007a). Particularly, the UNCCD advocates the involvement of women, youth and NGOs (UN, 1994). Hence, the Ghana's NAP was prepared as a result of extensive regional and district level consultative workshops on desertification and promoted active participation of local communities in addressing the challenges posed by desertification and land degradation (EPA, 2003). The NAP highlights seven major programme components that need attention in order to mitigate the effects of drought aimed at reducing the rate of desertification. Specific areas outlined to address land degradation within the NAP (EPA, 2003) include:

(1) Land use and soil management;
(2) Management of vegetative cover;
(3) Wildlife and biodiversity management;
(4) Water resources management;
(5) Rural infrastructure development;
(6) Energy resources management; and
(7) Improving socioeconomic environments for poverty reduction.

Many of these components cover adaptations which are considered central to achieving food security by sustaining rural livelihoods that are threatened by land degradation and desertification (EPA, 2003). Specific actions that seek to promote adaptation within these components include, but are not limited to, agro-forestry, provision of credit to farmers, promotion of off-farm enterprises, promotion of organic farming, creation of green belts around water bodies and the provision of better road networks linking rural farming communities as well as improving marketing of agricultural produce. Under efforts to improve the socioeconomic environment for poverty reduction, there is a food security action plan that highlights different programmes including the development and promotion of drought-tolerant crops. Indeed, practices such as agro-forestry as highlighted in the NAP, could promote rural development whilst mitigating climate change through carbon sequestration (Stringer *et al.*, 2012; Albrecht and Kandji, 2003).

8.3.3 Food and agriculture sector development policy and national land policy of Ghana

The FASDEP is the overall policy that guides the development and interventions linked to food and agriculture in Ghana (MoFA, 2007). The FASDEP has six policy objectives: 1) food security and emergency preparedness; 2) improved growth in income; 3) increased competitiveness and enhanced integration into domestic and international markets; 4) sustainable management of the land environment; 5) science and technology applied in food and agriculture development; and 6) improved institutional coordination. The major emphasis of this policy is to increase food production.

The National Land Policy (NAP) of Ghana (1999, revised 2002) aims to promote and encourage the judicious use of land to enhance the socioeconomic condition of Ghanaian society whilst ensuring that these land resources are sustainably managed for future use (MLF, 1999). According to Obeng-Odoom (2012, p. 164), the NAP has a vision "to individualise land rights and make interests in land easily tradable [in Ghana]". Land ownership in Ghana is based on absolute "alloidal" title (see Chapter 3). This means that all other rights to land are derived from these "alloidal" rights, which are normally invested in a stool, clan or skin (MLF, 1999). In some cases land title may be invested in a particular clan or particular families. The main policy provisions of the national land policy include facilitating equitable access to land, ensuring sustainable use of land, guaranteeing security of tenure and protection of land rights, and enhancing land capability and land conservation (MLF, 1999). In terms of equitable access to land, the policy indicates that an individual could access land in any part of the country provided that individual makes the necessary arrangements with the person who holds the title to that land.

8.4 Examining complementarity between the various policies in Ghana

An analysis of the relevant policy documents, through content analysis (see Chapter 3 for details), suggests that generally there seems to be complementarity between the INC and NAP and other policy documents relating to food production in Ghana. Most of the measures aimed at reducing land degradation and desertification identified in the NAP under UNCCD also seek to strengthen the coping capacity of farmers to climate variability (particularly drought). For example, the development and promotion of drought-tolerant crops identified in the NAP as an adaptive strategy is also linked to increasing resilience to climate change (INC) (Table 8.1). Further, both the INC and NAP recognise the need to diversify agricultural production to become less dependent on rain-fed agriculture. The FASDEP is appropriately linked to the Ghana National Poverty Reduction Strategy too, by ensuring that the agricultural sector plays a catalytic role in rural transformation through increased cash and food crop production (MoFA, 2007).

Ghana is mainstreaming climate adaptation strategies into national developmental agenda as widely called for in the literature (Kok and De Coninck, 2007; Huq *et al.*, 2004). For instance, the MEST, which plays a supervisory role in climate change adaptation in Ghana, also works in close collaboration with the National Development Planning Commission (NDPC), which oversees the development and implementation of appropriate developmental activities. The INC specifically highlights strategies to integrate national climate change concerns into Ghana's national development. These include reducing the emission of greenhouse gases by promoting the use of highly energy efficient appliances as well as the application of clean energy technology (EPA, 2001). Additionally, the need to reduce agricultural sector dependence on rain-fed farming systems is highlighted in the Ghana Poverty Reduction Strategy, which seeks to promote rural development and livelihood diversification (GoG, 2005). This could, indirectly, improve rural household's abilities to withstand climate variability as it enhances the financial assets base of such households.

Whilst there are shared goals across the policies that have been examined, there are also some conflicts. For instance, whilst the menace of climate change is clearly recognised in the INC and NAP, the FASDEP fails to articulate specific measures to help farmers cope with the adverse impacts of climate variability on their livelihoods. Further, the INC, NAP and FASDEP all fail to recognise the need to fully integrate local indigenous knowledge in finding solutions to the problems posed by climate change and desertification. Indeed, one of the key adaptation strategies identified in Chapter 6 is the use of local knowledge including social capital to plan farming activities to cope with drought. However, none of the policy documents highlighted this as a means of enhancing the coping capacity of rural households in farming communities in Ghana. Local people have coped with drought-related food insecurity with different ingenious practices, and these should be promoted in policy documents. This could facilitate the implementation of adaptation strategies as rural communities will appreciate and own such policy options.

8.5 Policy recommendations to reduce climate vulnerability

As already noted in Section 8.1, the findings of this thesis, together with the major themes that emerged from the content analysis of the various policy documents (Table 8.1), were presented to experts and stakeholders in a series of expert interviews, to elicit possible policy implications of this study. Table 8.2 presents the key policy recommendations that were highlighted by experts and stakeholders, and include mention of provision of credit facilities (86%; n = 18), livelihood diversification (71%; n = 15), the use of drought-tolerant crops (67%; n = 14) and improved institutional support (43%; n = 9). Others include construction of small dams (33%; n = 7), the development of region-specific adaptation policy (29%; n = 6), land tenure reforms (29%; n = 6), improved access to markets (19%; n = 4), using weather based insurance schemes (19%; n = 4) and increased education and awareness (14%; n = 3). About 10% (n = 2) of the experts indicated improving social relations within the study communities, with further 10% (n = 2) identifying integrating local indigenous knowledge with scientific assessments as critical to enhance resilience in the resilient communities whilst at the same time reducing climate vulnerability in the vulnerable communities.

Expert advice on policy recommendations were in agreement with the main themes identified in existing policy documents including the INC, NAP and FASDEP in relation to climate change adaptation and food security (Table 8.1). For example, the use of drought-tolerant crops, provision of credit facilities, agricultural diversification and strengthening extension services (that emerged through content analysis in Table 8.1) were all highlighted in the various policy recommendations (identified through expert interviews in Table 8.2). These, notwithstanding, as shown in Table 8.3, there were certain policy options that emerged from the expert interviews that were not covered in the existing policies. These include the development of region-specific adaptation policy and encouraging weather-based insurance schemes. Others include improving social relations within farming communities to cope with drought as well as integrating local indigenous knowledge with scientific adaptation assessments. Hence, it is recommended that future reviews of the existing policies as highlighted in Section 8.3 should take proper cognisance of these policy options that emerged from expert policy interviews whilst at the same time fostering efforts to implement those options already covered in the existing policies.

Table 8.3 provides the aim of the policy options, the spatial scale of possible implementation, the main stakeholders involved as well as the existing policy being targeted. Each of the policy recommendations identified from the expert interviews is expanded on in the following sections.

8.5.1 Provision of credit facilities and subsidies on agricultural inputs

Results from Chapter 7 suggest that a lack of financial resources constitutes a major barrier to climate adaptation by households in the study communities. The majority of the experts (86%; n = 18) shared the opinion that farmers should be given adequate credit facilities to enable them to implement appropriate climate adaptation strategies. Also, a lack of financial resources was mentioned by 92% (n = 248) of households sampled as a major barrier to climate adaptation. Hence, there is the need to make credit facilities accessible to small-scale farmers to enable them to purchase the necessary agricultural inputs at the appropriate times of the year.

In this regard, the following policy actions are proposed:

- Government should liaise with banks to extend credit facilities to farmers because most farmers cannot provide the necessary collateral that banks demand for the provision of credit. The government of Ghana through its agencies such as MoFA can act as guarantor to facilitate this.
- In Chapter 7, the thesis demonstrated that timing of financial assistance to farmers is critical. It is significant to stress that it is most desirable to give financial assistance to farmers at the beginning of the farming season when they need to e.g. hire tractors to prepare their farm lands and purchase farm inputs in order to take advantage of the early rains. This means that the processes involved in granting credit facilities and loans to farmers should be initiated well in advance of the farming season (see seasonal calendars in Tables 7.2 and 7.3).
- Related to the extension of credit facilities is the issue of the re-introduction of subsidies[30]. The removal of subsidies as a result of the structural adjustment programme of the International Monetary Fund embarked upon by the government of Ghana in the 1980s meant that the government could no longer support subsidies on agricultural inputs such as fertilizers, seeds and other agrochemicals (Konadu-Agyemang, 2000). This has had serious repercussions for agricultural productivity. The next review of the FASDEP should give considerable attention to this policy recommendation.

[30] The introduction of fertilizer and seed starter packs for maize in Malawi in 1998 improved maize production for small-holder farmers (Harrigan, 2008). However, the introduction of subsidy should be part of overall rural development strategy meant to improve food security (Harrigan, 2008). The subsidy programme should focus on main staple food crops such as maize, millet and sorghum that have potential to improve food security but are constrained by poor soil fertility (Dorward and Chirwa, 2011). Poorer households should be targeted in such agricultural subsidy programmes (Dorward and Chirwa, 2011).

Table 8.2: Policy recommendations identified through expert and stakeholders' interviews (*n* = 21)

Policy option	**No. of experts who mentioned this**	**Illustrative quotations by experts**
Provision of credit facilities & subsidies	18	*"Climate adaptation strategies such as planting drought tolerant crops, planting early maturing crops, use of irrigation require money and therefore there is the need for government to support farmers"* [UNFCCC focal point, EPA, Accra, August, 2011].
Livelihood diversification	15	*"One of the best ways to reduce the vulnerability of farmers [to climate change] is to encourage them to diversify their livelihood sources into non-farm income sources that are less vulnerable to the changing weather patterns. There is the need for government interventions in terms of providing the necessary training to be able to do this"* [Expert, EPA, Accra, August, 2011]
The use of drought-tolerant crops	14	*"We should encourage farmers to adopt new crop varieties that are drought*-tolerant and early maturing*. In this case, government should pay attention to research into drought-tolerant crops that are able to withstand erratic rainfall patterns* [Seed Breeder, Crop Research Institute, Kumasi, August, 2011].
Increased institutional support	9	*"We need to have a more resourceful extension service in terms of logistics and personnel to address the need of farmers"* [Expert, Ministry of Food & Agriculture, Accra, August, 2011]
Construction of small dams	7	*"We need to construct dams to provide irrigation facilities for vulnerable communities to enable them practise dry season vegetable farming. We can also educate farmers on improved water harvesting technologies so that farmers will be able to harvest water during the raining season"* [Regional Officer, WRC, Bolgatanga, July, 2011].
Development of region-specific adaptation policy	6	*"Whilst we acknowledge that Ghana as a whole faces serious problems with climate change [particularly drought], it is also obvious that the three northern regions (Northern, Upper East and Upper West) experience peculiar problem and need specific policies to enhance the capacity of farmers in such regions to cope with the adverse impacts of climate variability"* [UNCCD focal point, EPA, July, 2011].
Land tenure reforms	6	*"There is the need to reform land tenure systems to make land more accessible for agricultural production and to implement adaptation measures. This is particularly important for female farmers"* [Expert, Lands Commission, July, 2011].
Improved access to market	4	*"If farmers cannot sell their agricultural produce to pay off their loans, they will find it difficult to get future loans and this can affect their ability to cope with climate variability"* [Expert, International Institute of Water Management, July, 2011]
Weather based insurance scheme	4	*"Climate change will continue to adversely affect our food systems and we need to encourage farmers to grow more risk crop (such as maize) that have the potential for food security through weather-based insurance as a way of compensating farmers for potential crop losses associated with climate variability"* [Expert, University of Ghana, Legon, August, 2011].
Increased education and public awareness	3	*"We need to increase education on the menace of climate change to the populace in order to have increased awareness of climate change and desertification"* [Expert, EPA, July, 2011].
Improving social capital in communities	2	*"We have to highlight the need to improve social relations in our communities. The social inter*-*dependency that characterised these communities when I was growing up in the 1960s is no longer effective"* [Expert, Accra, 2011].
Integrating local knowledge with science	2	*"Our forefathers relied on their indigenous knowledge and passed these onto us. Hence, the need to recognise such local knowledge in devising climate change adaptation options for farmers"* [Stakeholder, Bongo, August, 2011].

Table 8.3. Scale of implementation and stakeholders involved in policy recommendations identified by experts and policy makers

Proposed recommendation	Aim of policy recommendation	Stakeholders involved*	Scale of implementation	Targeted policy*	Emerging policy options
Provision of credit facilities and agricultural subsidies	Make credit and farm inputs more accessible to farming communities.	MoFEP, MoFA	Multi-scale: national & community scales	FASDEP, NCCAS	Development of region-specific adaptation policy
Livelihood diversification	Equip vulnerable farmers to engage more in alternative non-farm livelihood activities.	NGO (such as World Vision), MoLGRD	At the community & household scales	FASDEP	Weather based insurance schemes
Development of drought-tolerant crops	Enhance research into drought-tolerant crops to make them easily accessible to farmers.	MoFA, EPA, MoE	Multi-scale: national, regional, district & community scales	FASDEP, NCCAS, NAP.	Improving social relations to cope with drought
Provision of institutional support	Improve delivery of extension services and information on climate change adaptation.	MoFA, GMet, MoI	Multi-scale: national, regional, district & community scales	FASDEP, NAP & NCCAS.	Integrating local knowledge with scientific assessments
Construction of small dams	Promote dry season farming in vulnerable communities where there are seasonal droughts.	MoLGRD, MoFA. WRC	Community scales	FASDEP	
Development of region-specific adaptation policy	Promote specific adaptation policy adapted to the local socioeconomic conditions.	MEST, EPA.	Multi-scale: Regional & community scales	NAP, NCCAS.	
Land tenure reforms	Increase accessibility of land by female and migrant farmers.	MoFA, MLF.	Multi-scale: national, regional & community scales	NLP	
Improve access to market	Improve efficient marketing of agricultural produce.	MoLGRD, MoFA.	Multi-scale: national, regional & community scales	FASDEP, NCCAS & NAP	
Using weather based insurance schemes	Reduce losses associated with drought incurred by farmers.	MEST, EPA	Multi-scale: national & community scales	FASDEP, NCCAS	
Increased education on climate change	Highlight the menace of climate change.	MoE, MoI, EPA.	Multi-scale: national, regional & community scales	NAP, NCCAS	
Improving social capital in communities	Improve social capital within communities.	Traditional authority, EPA, NGOs	Community scale	NCCAS, FASDEP	
Integrating local knowledge with science*	Recognise the value of local knowledge for climate adaptation.	Traditional authority, MoE, MoI	Community scale	NCCAS	

*EPA = Environmental Protection Agency, MoFEP = Ministry of Finance & Economic Planning, MoFA = Ministry of Food & Agriculture, MoE = Ministry of Education, MoI = Ministry of Information, MoLGRD = Ministry of Local Government & Rural Development, MLF = Ministry of Land & Forestry, WRC = Water Resources Commission, FASDEP = Food & Agriculture Sector Development Policy, NCCAS = National Climate Change Adaptation Policy, National Land Policy, NAP = National Action Programme to combat desertification.

8.5.2 Livelihood diversification

About 71% (*n* = 15) of the experts that were interviewed highlighted the need for farming households to diversify their livelihood strategies to be able to cope with the impacts of climate variability and change (Table 8.3). Results from Chapter 5 suggest that households that undertake a wider range of livelihood activities were less vulnerable to the adverse impacts of climate change and variability, while households that depend solely on crop farming were more vulnerable. Based on these findings, the thesis suggests the following policy actions:

- Appropriate programmes that seek to foster asset building such as skills training and craftsmanship should be integrated into the national climate change adaptation strategy to enable farming communities such as those in the study regions to venture into non-farm livelihood strategies.
- As highlighted in Chapter 6, livestock rearing is one of the principal non-arable farming alternative livelihood opportunities, especially for households in the vulnerable communities. Hence, efforts should be made to develop local expertise aimed at enhancing the production of livestock in these communities through regular workshops on livestock production.

8.5.3 Development of drought-tolerant crops

One of the major findings from Chapter 6 is that households are using drought-tolerant crops to cope with climate change but most of them lack the financial resources to access such varieties. It is therefore recommended that policy makers should enact appropriate policies that will improve the accessibility of drought-tolerant crops to farmers, especially those in the vulnerable communities. This thesis suggests the following policy actions:

- As already noted in Section 8.5.1, government should make credit facilities more accessible to rural farmers and also at the right time, possibly at the beginning of the farming season when such funds are mostly needed to invest in agricultural inputs including drought-tolerant crops.
- In particular, efforts should be made to enhance research into drought-tolerant varieties of crops such as maize, rice, sorghum and millet that hold great prospect for food security. The government of Ghana can access and invest part

of the climate adaptation fund into research activities related to drought-tolerant crops. Again, findings from such research should be extended to farmers through extension services and radio communication in local dialects.

8.5.4 Improved provision of institutional support to farmers

The lack of climate adaptation information including institutional support in terms of adequate all-year-round extension services was highlighted as one of the major barriers to implementing appropriate climate adaptation strategies by households in the study community (see Chapter 7). Experts were of the opinion that the government, through the Ghana Meteorological Agency, should improve access to information on climate variability including information on the distribution of rainfall during the farming season. The following policy actions are proposed:

- The government should invest heavily in early warning systems on drought and floods to aid farmers in planning their farming operations. It is recommended that appropriate communication mechanisms including the use of local radio stations broadcasting in local dialect could be used to ensure that such climate information and warnings reach the intended farmers.
- Efforts should be made by policy makers to improve farming practices by strengthening the capacity of extension officers through increased staff numbers and training of staff with different specialisms linked to different crops, especially staple crops such as maize, rice, sorghum and millet.
- There is the need to enhance coordination among the various institutions and agencies involved in climate change adaptation. It was discovered during expert interviews that data on climate change are quite fragmented at various institutions and agencies, making proper assessment of adaptation options quite difficult.

8.5.5 Construction of small dams for dry season farming

It is significant to emphasise that households, especially those in the vulnerable communities, have one farming season from June–September. This, coupled with poor soils due to inherently low soil fertility (Quansah, 2004; Oteng *et al.*, 1990) and their inability to purchase fertilizers due to extreme poverty, makes it quite difficult for such households to obtain adequate yields. Hence, any interruption in the rains during the farming season could have devastating effects on food security. Although there are a few irrigation facilities available to farmers, especially those at Vea, Fumbisi and Tolon, the majority of farming communities in the Upper East region do not have access to irrigation. One of the policy recommendations is therefore the development of irrigation facilities through the construction of small dams within these farming communities for farmers to practise dry season farming. According to MoFA (2007), irrigation would be possible on an estimated 33,400 ha in the Upper East region (vulnerable region). Therefore, the thesis suggests the following policy actions:

- Households should be educated on and encouraged to use improved water harvesting technologies in order to harvest rain water during the rainy season and use such water for dry season farming.
- Construction of small dams should be mostly targeted at the households in the vulnerable communities where there is only one short farming season, making rain-fed farming in such communities extremely unattractive because of lower yields due to climate variability.

8.5.6 Development of region-specific climate adaptation policies

An analysis of the NCCAS shows that the prioritised adaptation strategies are not region-specific. However, findings presented in Chapters 4 and 5 point to the fact that food production systems' vulnerability to climate variability in Ghana is spatially and socially differentiated. This provides empirical evidence to aid policy makers to target the most vulnerable communities and households for resource allocations and other policy recommendations in order to reduce vulnerability. Different ecological zones in Ghana have peculiar physical and socioeconomic characteristics that define their sensitivity and resilience to the impacts of climate change and variability. The following policy actions are suggested:

- Within the national climate change adaptation strategy, policies and programmes should by initiated and implemented to reduce the vulnerability of the most vulnerable households and communities.
- Vulnerability reduction should be linked to poverty reduction through the Ghana Poverty Reduction Strategy. Findings in Chapter 4 revealed that food

production systems' vulnerability to climate variability is directly related to the poverty level of a particular region and poverty is highly spatialised in Ghana.

8.5.7 Land tenure reforms to increase accessibility to lands by farmers

The issue of gender and land tenure in relation to sustainable development has attracted wide attention from civil society, gender activists and development partners (Adolwine and Dudima, 2010). Access to and ownership of farm land remains one of the greatest challenges confronting farmers, especially female farmers in the vulnerable communities and migrant farmers in the resilient communities, in implementing appropriate climate adaptation strategies (see Chapter 7). Though women generally have access to land, security of ownership is not always guaranteed. There remain cultural biases and discrimination against women in terms of access to and ownership of land in the study communities, especially in the vulnerable communities. This is very common in most SSA countries (e.g. Adolwine and Dudima, 2010; Quan *et al.*, 2004; Whitehead and Tsikata, 2003).

As already mentioned in Chapter 3, in the vulnerable communities, inheritance of farm land is through male heir and female right of usufruct is not recognised by the traditional land inheritance system (Yaro, 2010). Hence, women access farm lands through marriage or male children. Experts and policy makers in a series of in-depth interviews stressed the need to reform the land tenure policies in Ghana. Based on these findings, the thesis makes the following policy suggestions:

- Women's rights regarding land ownership are not comprehensively covered in the current national land policy. Hence, there is the need to institute appropriate measures to reduce or eliminate these cultural discriminations against women. This could be achieved by restructuring the land tenure system to ensure that the rights of women on land ownership are fully recognised and granted. This will require intensive education programmes to sensitise chiefs, Tendanas and other opinion leaders who are custodians of farm lands in these communities, on the need to recognise women in decision-making relating to land tenure arrangements.
- The government of Ghana could also encourage block farming, whereby the government rents a vast area of farm land and distributes this to various

households to produce various agricultural crops. Households may be provided with farm inputs such as seeds and fertilizers. This affords vulnerable households, which otherwise would not be able to access such farm lands and inputs, the opportunity to improve their livelihoods. This will be particularly a policy intervention for marginalised female-headed households that were culturally discriminated by land ownership and acquisition practices in the vulnerable communities (see Chapter 7). Careful criteria would need to be drawn up to determine eligibility.

8.5.8 Improved access to markets by farmers

The lack of readily available markets in the study communities is perceived by households sampled in this study as a barrier to effective climate adaptation as it limits options. Therefore, this thesis proposes the following policy actions:

- Concerted efforts should be made to improve road infrastructure and transport to facilitate the transportation of farm produce to the market centres to enable farmers to sell their crops to pay off their loans in order to remain credit worthy. Indeed, social factors such as access to transport infrastructure could greatly influence how farmers respond to climatic stress (Reid and Vogel, 2006). There is an urgent need to improve the road networks, especially in the vulnerable communities, to get produce from the field to the market.
- The government, through its principal agents such as the Agricultural Development Bank, could make special arrangements to purchase food stuffs from farmers especially during the peak period where farmers find it extremely difficult to access markets for their produce. In this case, farmers could be guaranteed a pre-determined price for agricultural produce so as to encourage farmers to produce more.

8.5.9 Managing drought through provision of weather-based insurance

Presenting the findings of this study in a series of expert interviews revealed that one of the ways to reduce losses by farmers will be to provide and promote weather-based index insurance for farmers (Table 8.3). The key underlying weather-based index insurance is that the government through its principal agencies provide insurance against specific climatic events like droughts that could destroy crops (Hazell and Hess, 2010; Linnerooth-Bayer and Mechler, 2006).

Though weather based insurance is still in its early stages of development, it is quite promising and could be explored to manage agricultural production risk in Ghana and more widely in SSA (Hess and Syroka, 2005). One major potential caveat for the uptake of this, however, is the lack of adequate local weather stations in Ghana. This notwithstanding, a crop insurance feasibility study suggests that appropriate climate data exist for the design of weather based crop insurance scheme in Ghana (Stutley, 2010). This insurance could encourage many farmers to grow more food crops knowing that their crops are properly insured should there be any drought events. To achieve this policy recommendation, the following actions are proposed:

- The Ghana Meteorological Agency will need to be fully resourced in order to provide accurate and reliable rainfall data to facilitate the administration of such weather-based index insurance schemes.
- The government of Ghana could explore the possibility of utilising part of its climate change adaptation fund set up by the government under the UNFCCC to subsidise this innovative insurance scheme to assist vulnerable households whose livelihoods depend entirely on rain-fed agriculture[31].
- There should be concerted efforts by government agencies including extension officers at the district, regional and national levels to create the necessary cultural awareness in order to increase the appeal of weather-based crop insurance to farmers.

8.5.10 Increased education and awareness on climate change

The results presented in Chapter 6 suggest that households in the study regions are quite perceptive of the changing climate. Particularly, households perceived increasing temperature and a decreasing rainfall amount in the study regions. These observations could be put to good use in terms of climate adaptation. Farmers are more likely to

[31] It could also help farmers to secure credit facilities from banks once there is a guarantee that losses associated with drought events can be redeemed from the insurance package. Hence, farmers that are insured will find it relatively easier to access credit and use part of this credit to purchase such insurance products. Agricultural insurance has been shown to increase access to agricultural loans by farmers in India (Stutley, 2010).

invest in adaptation strategies if they can perceive changes in the climate (Maddison, 2007). In this regard, the following policy actions are proposed:

- Environmental education aimed at creating awareness of the changing climate patterns and the associated adverse effects on the livelihoods of many agriculture-dependent communities should be promoted. The Marrakesh Accord encourages parties to the UNFCCC to build capacity in climate change by improving education and public awareness of the menace of climate change. In this case, environmental education should be vigorously pursued under the national educational curriculum. This will ensure that children grow to adopt environmentally friendly lifestyles. Although such environmental education is highlighted in the NAP, further efforts are needed. Perhaps the slow progress to date is due to a lack of funds to implement appropriate programmes that will endear environmental education into the citizenry.
- National educational institutions should encourage and promote the teaching and learning of issues relating to sustainable development and climate change through the establishment of sustainability school clubs across Ghana, so as to inculcate the ideas of green behaviour and green consumerism into the Ghanaian society.
- To encourage and motivate researchers, it is suggested that the government, through the Ministry of Environment, Science and Technology, establishes a special fund dedicated to funding research activities relating to climate change issues.

8.5.11 Enhancing social capital in farming communities

One of the main findings from this thesis is that outlier households that demonstrated relative resilience even in more vulnerable communities were well-socially connected, enabling them to take advantage of environmental and economic opportunities (Chapter 5). Such households have access to both bonding social capital through ties within such communities, and bridging social capital as a result of the various political positions that give them role as opinion leaders and decision makers for such vulnerable communities. In this regard, the following policy actions are proposed:

- Efforts should be made to improve and encourage social relations amongst households within the study villages. This will improve social-exchange networks that are critical for sustaining livelihoods in the face of climate variability.

- Households should be encouraged to engage in social relations so as to share information on climate adaptation within these villages. This could be done through the formation of community-based associations and farm-based groups. Forming these associations will not only give such households access to social capital, but will also offer them opportunities to access loans from banks and other financial institutions. The risky nature of most rain-fed agriculture deters most financial institutions from giving loans to individual farmers. Such institutions would rather give loans to recognised groups and associations.

8.5.12 Integration of indigenous knowledge with scientific assessments

It is further recommended that local indigenous knowledge on climate adaptations should be synthesised. Rural households in dryland farming systems in Africa have used their local knowledge to develop coping strategies to buffer against risk and uncertainties in the weather (Roncoli *et al.*, 2002; Thomas *et al.*, 2007). Chapter 6 presents empirical evidence that suggests households are increasingly relying on their local indigenous agro-ecological knowledge to form complex climate models based on their past experience to adapt to climate change and variability. Therefore, this thesis suggests the following policy actions:

- Local indigenous agro-ecological knowledge should be considered and appropriately integrated with scientific climate assessments in the design and implementation of climate adaptation strategies (see Chapter 6) as widely called for across the climate and development policy literature (Nyong *et al.*, 2007; Orlove *et al.*, 2010; Stringer *et al.*, 2009; Newton *et al.*, 2005). Adaptation strategies that acknowledge local contexts, such as belief systems and indigenous knowledge, are increasingly sought after (Jennings and Magrath, 2009).
- The capacity of local farmers should be built to enable them to cope with the adverse impacts of climate change by identifying early warning signals of climate change and variability. However, this should be undertaken in tandem with the existing local knowledge as highlighted above.

8.6 Conclusions

This chapter explored possible policy implications of this research. The chapter has revealed that, generally, there are synergies between the national action plans related to the UNFCCC for climate change and UNCCD for desertification. The key themes that emerged from the policy analysis, together with the findings of this study, were presented to experts and stakeholders in a series of experts interviews. Based on this exercise, a number of policy recommendations were identified. Notable amongst these recommendations include the provision of credit facilities and subsidies to farmers, diversification of livelihood activities, the use of drought-tolerant crops and land reforms to make land more accessible to female farmers to implement adaptation strategies. Others include the development of region-specific adaptation policies and programmes, construction of small dams for dry season farming, as well as increased provision of institutional support including building extension capacity. Additionally, education and awareness of climate change should be vigorously pursued to generate environmentally sound behaviours, as well as the provision of innovative weather-based index crop insurance to enable farmers engage in high risk crops that may be more vulnerable to drought. Finally, policy makers need to encourage and strengthen social-exchange relations in farming communities and seek ways of integrating local knowledge into scientific adaptation assessments, as widely called for in the literature.

When implemented successfully the policy recommendations outlined in this chapter could reduce the overall vulnerability of Ghana’s food production systems and livelihoods to climate variability (particularly drought). Ultimately, this will reduce the level of food insecurity in rain-fed agriculture-dependent communities in rural Ghana and more widely. Notwithstanding, it is acknowledged that these policy recommendations will be implemented within constrained resourcing environments. For instance, the implementation of most of these policy recommendations requires significant financial investments and given the current developmental challenges confronting Ghana, it is envisaged that serious efforts will be needed on the part of policy makers to address barriers to successful implementation of climate adaptations.

CHAPTER 9

SUMMARY, CONCLUSIONS AND REFLECTIONS

9.1 Introduction

The aim of this thesis was to explore the socioeconomic, institutional and biophysical factors that contribute to vulnerability to climate change and variability of households and communities in Ghana. Using an interdisciplinary and a mixed method, multi-scale approach, this thesis employed spatial data and field-based participatory studies to:

(1) Identify vulnerable and resilient regions, districts and communities in Ghana;

(2) Characterise and explain the nature of vulnerability to climate variability;

(3) Determine adaptation strategies being adopted to manage climate variability;

(4) Identify the barriers to climate adaptation strategies; and

(5) Suggest policy recommendations to reduce vulnerability of Ghana's food production systems and livelihoods to climate variability.

This concluding chapter summarises the key findings and explores the implications for food security in Ghana and more widely.

9.2 Identifying where food production systems and livelihoods are most vulnerable to drought

Using an innovative multi-scale quantitative approach to vulnerability assessment, this thesis has established where within Ghana food production systems and livelihoods are most vulnerable to drought. Empirical data presented in Chapter 4 illustrated that the vulnerability of crop production to drought has discernible geographical and socioeconomic patterns, with the Northern, Upper West and Upper East regions being most vulnerable. The results demonstrated that these regions have the lowest adaptive capacity due to low socioeconomic development, and have economies based mainly on rain-fed agriculture.

The methodological approach outlined in Chapter 4 illustrated how a quantitative national and regional multi-scale vulnerability assessment is a critical (and often ignored) first step in assessing differences in the drought sensitivity of food production systems across large areas. Further, the approach guided the formulation of more targeted district and community level research that explored the drivers of vulnerability and change on a local-scale. The methodological approach has wider significance as it can improve drought sensitivity and vulnerability assessments in dynamic dryland farming systems where there are multiple drivers of change and thresholds of risk that vary in both space and time (Reynolds *et al.*, 2007). The results also demonstrate the need for region-specific policies to reduce vulnerability and enhance drought preparedness within dryland farming communities. By developing and applying such an integrated suite of quantitative approaches for climate change vulnerability assessment, this thesis contributes to geographical and scientific debates on the development of integrated vulnerability assessments that can be applied in geographical areas for which detailed data may be lacking.

9.3 Characterising the nature of climate vulnerability

Using a livelihoods approach, the data presented in Chapter 5 characterised and explained the nature of climate vulnerability at the household and community levels. By characterising the nature of vulnerability to climate variability through a focus on food production and livelihoods, this thesis has enhanced our understanding of the drivers of vulnerability to climate variability in rain-fed agricultural systems. It was found that within the same agro-ecological setting, different communities and households experience differential vulnerability that may be attributed to differences in socioeconomic characteristics. The thesis also confirmed that the vulnerability of farming communities can be linked to access to livelihood capital assets (Bebbington, 1999; Moser, 1998), and that vulnerable communities tend to have households that are characterised by low levels of human, natural, financial, physical and social capitals.

Results identified vulnerable households within the resilient communities as well as more resilient households within vulnerable communities. These were referred to as outliers and offered valuable insights into vulnerability at the household level. For instance, the outlier households in vulnerable communities have an array of alternative livelihood options and tend to be socially well-connected, enabling them to take advantage of opportunities associated with environmental and economic changes.

Identifying such outlier households provides valuable insights into the drivers of vulnerability, even in relatively resilient communities. This finding has wider significance as it builds on previous research on livelihood diversification (Sallu *et al.*, 2010; Barrett *et al.*, 2001; Ellis, 1998; Paavola, 2008) and highlights the need to support rural households to develop non-farm livelihood activities that can reduce the impacts of drought.

In addition, this thesis has provided a nuanced understanding of how different households could be affected by climate variability. Empirical evidence in Chapter 5 reaffirms previous studies e.g. Kakota *et al.* (2011) and Glazerbrook (2011), that suggest that female-headed households without any reliable non-farm income jobs could be more vulnerable than male-headed households. Given the future projected climate change in Ghana and SSA more widely (Boko *et al.*, 2007; Christensen *et al.*, 2007), it is expected that such households will become more vulnerable unless they are supported through appropriate policies aimed at reducing drought vulnerability. The implications of these results are that policy makers need to identify and provide appropriate interventions that foster asset building, improve institutional capacity and social capital so as to enhance the livelihoods of rural farming households and communities.

9.4 Exploring adaptation strategies for managing climate variability

Empirical data in Chapter 6 revealed that households in the study communities were employing a range of on-farm and off-farm adaptation strategies to mitigate the negative impacts of drought on their livelihoods. Farmers employed on-farm adaptation strategies such as changing the timing of planting, planting drought-tolerant crops and early maturing varieties, diversifying their crops, using crop rotation and using irrigation. Off-farm adaptation strategies included livelihood diversification, temporary migration, relying on social networks, using traditional agro-ecological knowledge, changing diets, relying on governmental and NGOs assistance as well as reducing food consumption to manage climate variability.

One of the more significant results that emerged is that most farming households and communities were using coping strategies that are linked to livelihood diversification and that most of these households were using a range of non-farm livelihood diversification strategies in an attempt to avoid destitution because of crop failure linked to drought. Such strategies include petty trading, selling livestock, hat and basket weaving, tailoring, sand mining, working as forest assistants, charcoal production, shea nut picking and carpentry. These activities are being pursued by households as complementary livelihood options.

Building on previous studies (e.g. Below *et al.*, 2012; Deressa *et al.*, 2009; Bryan *et al.*, 2009), the findings showed that socioeconomic factors such as gender, age, wealth (based on local perception), education level, land tenure system as well as agro-ecological setting could influence the choice of adaptation strategies used by households in the study communities (Chapter 6). Policy makers need to consider these socioeconomic factors when designing climate adaptation policies, such as enabling farmers to engage in alternative livelihood diversification strategies, aimed at reducing the adverse impacts of drought on rural livelihoods. Further, appropriate programmes that seek to foster asset building such as skill training and craftsmanship should be integrated into the national climate change adaptation strategy to enable farming households to venture into non-farm livelihood strategies.

9.5 Identifying barriers to adaptation to climate variability

Empirical evidence in Chapter 7 provides useful insights into the nature of barriers to climate adaptation by small-scale farmers in rain-fed agricultural systems. Farming households and communities are confronted with a range of barriers in their attempts to adapt to climate variability. Notable amongst these barriers was a lack of financial resources, which was reported by 92% (n = 248) of study households. A lack of financial resources is also linked to other barriers to adaptation such as the high cost of improved varieties and a lack of farm implements and machinery.

Poor access to information on climate adaptation, complex land tenure systems, and social-cultural barriers and gender issues are other challenges that confronted households in their attempts to implement climate adaptation strategies. Limited access to improved varieties of crops such as maize and millet, lack of markets as well as a lack of institutional support in terms of adequate all-year-round extension services constituted serious barriers to climate adaptation. It should be acknowledged that most of these barriers also relate to agricultural production more broadly and impede adaptation to factors in addition to climate change. By identifying these barriers to climate adaptation, this thesis has provided policy recommendations as to how farmers could be supported to reduce livelihood and food production system's vulnerability in Ghana (see Section 9.6). These recommendations are also likely to be more widely applicable beyond Ghana.

9.6 Identifying policy implications of the study

Taken together, the findings presented in this thesis (Chapters 4–7) have implications that need to be carefully considered by policy makers in order to reduce food production systems and livelihoods' vulnerability to drought in Ghana and SSA more widely. Chapter 8 highlighted the main policy options that were identified through expert interviews with various experts and stakeholders. These include:

- The provision of credit facilities and subsidies on agricultural inputs to farmers;
- Enabling farmers to engage in alternative livelihood diversification strategies;
- Promoting the development and planting of drought-tolerant crops;
- Improving the provision of institutional support including access to information on climate adaptation and adequate all-year-round extension services;
- Construction of small dams and improving water harvesting technologies aimed at promoting dry season farming;
- Development of region-specific climate adaptation policy;
- Land tenure reforms to increase accessibility and ownership of lands by farmers, especially female and migrant farmers;
- Improving access to markets for agricultural produce;
- Managing drought through provision of weather-based index insurance schemes;
- Increasing education and awareness on climate change and variability;
- Improving social capital in vulnerable communities;
- Integrating local indigenous farming knowledge with scientific assessments.

These recommendations should be initiated through a focal point within the Ministry of Environment, Science and Technology, through the Environmental Protection

Agency. The recommendations should also be embedded in the appropriate ministries such as the Ministry of Food and Agriculture and Ministry of Land and Forestry (see Figure 8.1). In this regard, it is recommended that the Ministry of Environment, Science and Technology, is supported by the National Climate Change Committee and National Development Planning Commission to ensure that these recommendations are mainstreamed into national developmental agenda.

9.7 Methodological reflections on the multi-scale drought vulnerability assessment

This thesis used a mixed-method, multi-scale approach to assess the vulnerability of food production systems and livelihoods to climate variability at regional, district, community and household levels in Ghana. Climate change is a complex problem interacting with different processes at different geographical scales (Cash and Moser, 2000; Wilbanks, 2002). The use of mixed-method approaches allowed the validation and deepening of understanding of the main issues involved in vulnerability of livelihoods and farming systems to climate variability through triangulation, thus providing a significantly richer understanding of the different dimensions of the problem through its exploration across scales. Combining different methods to enable input from local farmers through participatory approaches provided local insights to enhance understanding into how past climate events shape livelihoods activities of agriculture-dependent communities. This is especially important in the face of new and unfamiliar climatic conditions, where local knowledge could be a useful source of information for community adaptation to climate change and variability, so such dialogue between community members is valuable.

The multi-scale integrated approach for drought vulnerability assessment in Ghana developed in this thesis has wider significance for dryland farming systems across Africa. Most vulnerability assessments (e.g. Ericksen *et al.*, 2011; Simelton *et al.*, 2012; Midgeley *et al.*, 2011; Abson *et al.*, 2012) have been conducted at only one scale, using either quantitative or qualitative methods (see Chapter 2), although attempt by O'Brien *et al.* (2004b) to undertake multi-scale vulnerability analysis is acknowledged. Single scale assessments fail to fully capture the range of interacting socioeconomic and biophysical factors and processes operating at different levels to affect vulnerability.

Using an interdisciplinary approach, this thesis has addressed a significant research gap by integrating different participatory methods and ecological surveys to assess the extent of food production systems and livelihoods' vulnerability to climate variability across multiple scales: mapping drought vulnerability at the national and regional scales and drilling down to the community and household scales. Indeed, several authors have argued that climate change studies should move away from one-scale approach to a multi-scale approach (Adger *et al.*, 2005; Osbahr *et al.*, 2008; Cash *et al.*, 2006; Gibson *et al.*, 2000).

Whilst the mixed method, multi-scale approach adopted for this study has provided useful insights into the extent and drivers of food production system's vulnerability to drought, the socio-cultural context within which this study took place should not be ignored. Hence, caution should be exercised in generalising from the findings of this study because of the different contextual factors that influence vulnerability at the local-level. Therefore, assessing its wider applicability will require a larger sample size involving the different agro-ecological zones in Ghana to provide additional insights in relation to livelihoods and food systems' vulnerability to climate variability.

9.8 Priorities for future research

Despite the valuable insights provided, there remain a number of unanswered questions that require further research. First, further research is needed to refine the drought vulnerability assessment to enhance its wider applicability. For instance, research could explore the possibility of using daily rainfall data instead of monthly rainfall data for the construction of the exposure index in the vulnerability analysis. Similarly, the estimation of adaptive capacity could be improved if more proxy indicators such as irrigation potential of the various regions, access to credit, soil degradation index, farm assets and farm income were included. The consideration of such data would provide a significantly better understanding of the extent of livelihood and food production systems' vulnerability to drought in Ghana and SSA more widely. Second, about 36% of farming households that participated in the study cited the importance of social capital in mitigating the adverse impacts of drought. However, this thesis did not explore the extent of social capital and how this could be enhanced by formal and informal institutions. Therefore, there is the need for future research to explore how institutions could promote social capital for community adaptation to climate variability. Third, findings in this thesis demonstrate that land tenure is importantly involved in disposing two groups of households – migrant households in the resilient communities (located in the south) and female-headed households in the vulnerable communities (located in the north) – as vulnerable by limiting the access of these two groups of households to land. Further research is needed to enhance understanding of how different tenure systems in Ghana influence households' vulnerability to climate variability in dynamic dryland farming systems.

9.9 Concluding remarks

Livelihoods and food production systems in Ghana are generally vulnerable to climate variability. Spatial databases and field-based participatory studies were used in this study to develop and apply an innovative multi-scale approach for assessing vulnerability to climate change (especially in the form of drought sensitivity) to identify where agricultural livelihoods and food production systems are most vulnerable to drought. The methodological approach outlined in this thesis has wider significance for drought vulnerability assessments in dryland farming systems where drought is a serious threat to livelihoods. Coupled social-environmental assessments are characterised by spatial and temporal changes that pose significant geographical challenges in developing appropriate climate change vulnerability frameworks (Turner *et al.*, 2003). Hence, the use of a quantitative multi-scale approach supported by qualitative data through the use of focus group discussions, ecological surveys and expert interviews to drought vulnerability provides a useful contribution towards reliable and more comprehensive results that may be lacking in a single-scale approach. Findings in this thesis will contribute to a general discussion of the sorts of livelihoods and food production systems that enhance adaptive capacity to future climate changes and will inform future national policy developments.

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Appendices

Appendix 1: Household questionnaire

Demographic characteristics

1. (i) Age________________ (ii) Gender: Male or female (circle one)
2. Highest educational level

   (a) No formal education (b) Primary school

   (c) Junior secondary school (Middle School) (d) Senior secondary school

   (e) Tertiary education (University, Polytechnic, Professional Colleges)
3. Indicate household size. Please fill in the table below.

Sex	Children	Adults (age in years)			
	<18 years	18-30	31-45	46-60	> 60
Male					
Female					

4. When did you start farming?
5. Were you born in this village? If no, when did you move here and why?
6. Relative to other households in my community, my family is quite healthy.

(a) Strongly agree (b) agree (c) neither agree nor disagree (d) disagree (e) strongly disagree

Assessment of livelihoods capital assets

7. By what arrangement do you have access to your land for farming activities?

   (a) land purchased (b) land inherited (c) land rented (d) others
8. Could you please state the size of farm holding (average cultivated land for the past 5 years in hectares or acres)?
9. Do you have access to credit for your agricultural activities? Yes/no. If yes, indicate where you get credit. If yes, when do you get this credit? (a) at beginning of farming season (b) middle of farming season (c) after the farming season.
10. Do you have livestock or poultry? Yes/no. If yes, list the types and numbers of livestock or poultry.
11. Do you receive remittances from family or friends? Yes/no.

    If you answered yes to question 17, how often do you receive such remittances?

    (a) Very often (b) not often (c) sometimes

12. Do you have access to irrigation facilities? Yes/no (circle one) If yes, is this a commercial irrigation facility? Yes/no (circle one).

    (a) How far is this irrigation facility from your farm? State the distance in km.

    (b) Do you pay for using this irrigation facility? Yes/no (circle one)

    If yes, how much GHc/year ____

    (c) What percentage of your farmed land is under irrigation?________________

13. Could you please list all communication gadgets that you have? These include television, radios, mobile phones etc.
14. How would the communication gadgets listed above help you to access information on the weather?
15. Do you have access to ready markets for your agricultural produce? Yes/no, if yes, where and how long do you have to travel?

Livelihood activities and climate variability

16. What are your main livelihood activities? (Rank with 1 being the most important)

Livelihood activity	Rank	% of household income
1.		
2.		
3.		
4.		

17. How are these livelihood activities affected by changes in the climate?

Agro-ecosystems assessment

18. Please list the various crops you grow on your farm.

Crop	% of household income that this crop provides	% of land under cultivation for this crop	% of fields planted with hybrid seeds for this crop
1.			
2.			
3.			
4.			

19. How many mini bags of each crop listed above did you harvest last year (2009 or the average of the last 3 years, whichever is the larger).

20. How much did you realise in income from the sale of these crops? An estimated amount is provided based on the number of mini bags and the amount per bag.

21. How would you describe the quality of soil for crop production in your farm? (a) Very good (b) good (c) poor (d) very poor.

22. Do you pick non-timber forest products such as mango, snails, mushrooms and bush meat in this community? Yes/no, if yes, how often are you able to do that? (a) Very often (b) not often.

23. Do you rely on food from your own farm for the household? Yes/no. If no, where and how do you supplement this? Briefly explain.

24. Please indicate the type of pest control on your farm.

25. If you use fertilizers state whether chemical or organic fertilizers and why?

26. If you practise any soil-conservation techniques, please state these?

27. Do you practise mono-cropping or poly-culture? Briefly explain why?

Institutional arrangements

28. Do you belong to any social organisations or groups in this community or outside this community? Yes/no. If yes, please list these in the table below.

Type of organisation	Name of organisation	What type, if any, form of assistance from this organisation?
Faith-based		
Communal (social)		
Farmer-based		
Others		

29. List other governmental or non-governmental organisations that have assisted you in coping with drought-related food insecurity in the past.

Organisation	Type (NGO, FBO, governmental)	Form of assistance

30. Do you have access to information on seasonal forecasts for your farming activities? Yes/no (circle one) If yes, from where (please rank this with 1 being the most important source for you).

(a) Use of indigenous knowledge to predict weather patterns. Describe the nature of this knowledge.

(b) Rely on meteorologists and weather forecasts from radio and newspapers.

(c) Rely on information from friends/family/neighbours.

(d) Others (please specify) ____

31. Do you have access to extension advice for your farming activities? Yes/no

    Please describe the kind of advice

32. How often do you have such contacts with extension officers? (a) Very often (b) not often

Perception of climate change exposure and impacts

33. Have rainfall patterns changed in your life time? Yes /no (circle one)

34. Is there more or less rain today than in your childhood?

    Compared to my childhood, rainfall has (a) increased (b) reduced (c) same

35. Do the rains fall earlier or later than you remember from your childhood?

    Compared with my childhood, the rains come (a) earlier (b) later (c) same

36. When did you last have a 'good rainfall' year? (State year or number of years).

37. Have temperature patterns changed during the growing season in your life time? Yes/no (circle one). As compared to my childhood, temperature in the growing season has become (a) Hotter (b) Cooler

38. Do you consider the changes in

    (i) rainfall as a problem for your farming activities? Yes/no. Why and how?

    (ii) temperature as a problem for your farming activities? Yes/no. Explain?

39. Please identify the major climate problems experienced in the last 6 years

Year	Climate problem (drought or flood)	State the impacts on livelihoods
2005		
2006		
2007		
2008		
2009		
2010		

40. A major climatic problem (such as big flood or drought) that happened in the last 5 years is likely to occur in the next 5 years in this community. Do you agree with this statement?

    a) Strongly agree b) agree c) neither agree nor disagree d) disagree e) strongly disagree

Briefly explain why?

41. Have you received training to deal with the changes in rainfall and temperature patterns for your farming activity in the past 5 years? Yes/no, if yes, who organised this?

42. How would you describe a 'good rainfall year'? Show this in the table below.

Month	Normal Year	This year	In my childhood
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			

a. In a normal year, when do the rains start?

b. In a normal year, when do the rains end?

c. In a normal year, when are the rains heaviest?

Identification of adaptation strategies in farming communities

43. What are some of the ways you have used to cope with the changes in the climate in the past five years?

    (a) Planting late or early to avoid the drought. Why or why not?
    (b) Planting drought tolerant or resistant varieties. State these varieties.
        (i) Please since when did you start using these varieties and why?

        (ii) From where do you obtain drought tolerant varieties for planting?

    (c) Planting of various crops at different times

(d) The use of local indigenous knowledge. Please describe?

(e) Rely on friends/family/neighbours. In what form?

(f) Receive assistance from the government. In what form?

(g) Income from off- farm jobs (livelihood diversification). Briefly explain.

(h) Sell non-farm assets to cope with the changes in the climate.

(i) Temporary migration to work elsewhere. Where and doing what?

Would you move again as a strategy to cope with the changes in the climate? Yes/no. Briefly explain.

(j)Buy food or change diet. Please explain.

(k) Reducing food consumption

(l) Others (please specify)

44. Please rank the top three adaptation strategies you have used in the past. (1 being the most important and 3 being the least important).

(a) Changing timing of planting to avoid drought

(b) Planting drought tolerant/resistant varieties.

(c) Planting of various crops at different times (insurance against crop failure).

(d) The use of local indigenous knowledge.

(e) Rely on friends/family/neighbours.

(f) Receive assistance from the government.

(g) Rely on income from off- farm jobs.

(h) Sell non-farm assets to cope with the changes in the climate.

(i) Temporary migration to work elsewhere

(j) Buy food or change diet

(k) Others (please describe)

(a) Please list (and describe) the five most important things that you think could help this household to reduce its vulnerability to climate variability (please list these in order of importance).

Barriers to adaptation strategies in farming communities

45. Briefly explain which of the following prevent you from implementing these adaptation strategies highlighted above? You can tick as many as possible.

    (a) Lack of financial resources

    (b) Poor access to climate information

    (c) Lack of institutional support

    (d) Complex land tenure systems and gender issues

    (e) Social-cultural barriers

    (f) Lack of ready markets

    (g) High cost of and limited access to improved crop varieties

    (h) Lack of farm implements and machinery

    (i) Others (please specify)

Appendix 2: Question guide for focus group discussions

1. List all the capital assets in the farming community, which members of the community draw upon to achieve their livelihoods.

2. Arrange these into the five capital assets (i.e. natural, human, physical, financial, and social assets).

3. Highlight main climate events that have taken place in this community since the 1960s. How have these events affected your farming activities and other livelihoods?

4. How are these assets (and livelihood activities) vulnerable to changes in weather pattern?

5. How do the community adapt to these changes in the weather pattern?

6. What things prevent the community from implementing these adaptation strategies?

7. Are there any beliefs or social norms that prevent the community from taking certain decisions to respond to changes in the weather?

8. What institutions (organisations) do you as a community rely on for help due to the changes in the climate? What kinds of help?

Appendix 3: Species abundance in sampled agro-ecosystem (AS) and natural ecosystem (ES)

Species	Family	Individuals sampled in resilient communities			Individuals sampled in vulnerable communities		
		AS	ES	Overall	AS	ES	Overall
Acacia sieberiana	Fabaceae	0	0	0	0	20	20
Acacia noletica	Fabaceae	0	4	4	0	0	0
Adansonia digitata	Bombacaceae	0	0	0	2	6	8
Allophylus africanus	Sapindaceae	1	13	14	0	0	0
Anchomanes species	Arecaceae	3	2	5	0	0	0
Anogeissus leiocarpus	Combretaceae	0	10	10	0	0	0
Anonas senegalensis	Annonaceae	0	0	0	10	25	35
Azadirachta indica	Meliaceae	0	20	20	10	15	25
Borassus aethiopum	Arecaceae	0	1	1	0	0	0
Moraceae species	Moraceae	0	3	3	0	0	0
Bridelia micrantha	Euphorbiaceae	6	4	10	0	0	0
Calotropis procera	Ascelpiadaceae	0	0	0	0	9	9
Caspicum species	Solanaceae	3	0	3	0	0	0
Sida acuta	Malvaceae	99	48	147	0	0	0
Sida species	Malvaceae	8	2	10	0	0	0
Ceiba pentandra	Bombacaceae	33	0	33	0	0	0
Centrosema pubescens	Fabaceae	89	54	143	0	0	0
Combretum species	Combretaceae	20	105	125	0	0	0
Combretum ghalensis	Combretaceae	0	0	0	0	3	3
Combretum micranthum	Combretaceae	24	2	26	0	0	0
Combretum nigricans	Combretaceae	0	0	0	5	20	25
Danielle oliveri	Fabaceae	16	43	59	0	0	0
Desmodium species	Fabaceae	63	29	92	0	0	0
Detarium senegalense	Fabaceae	4	7	11	0	0	0
Dioscorea species	Diosceaceae	35	0	35	0	0	0
Diospyros mespiliformis	Ebenaceae	0	0	0	0	19	19
Elaeis guineensis	Arecaceae	1	5	6	0	0	0
Faidherbia albida	Fabaceae	0	0	0	17	54	71
Ficus capensis	Moraceae	3	1	4	0	0	0
Ficus exasperate	Moraceae	126	8	134	0	0	0
Ficus gnaphalocarpa	Moraceae	0	0	0	10	0	10
Ficus lepiri	Moraceae	0	0	0	5	5	10
Ficus species	Moraceae	0	10	10	0	0	0
Gmelina aborea	Verbenaceae	0	137	137	0	0	0

Indigo fera	Fabaceae	19	37	56	0	0	0
Ipomea species	Convolvulaceae	9	0	9	0	0	0
Kigelia africana	Bignoniaceae	0	14	14	0	0	0
Lannea acida	Anacardiaceae	0	0	0	15	35	50
Liana species 1	Linaceae	19	7	26	0	0	0
Liana species 2	Linaceae	4	30	34	0	0	0
Liana species 3	Linaceae	0	5	5	0	0	0
Liana species 4	Linaceae	1	4	5	0	0	0
Lippia species	Verbenaceae	8	110	118	0	0	0
Lophira lanceolata	Ochnaceae	18	0	18	0	0	0
Magnifera indica	Anacardiaceae	0	0	0	1	0	1
Mallotus oppositifolius	Euphorbiaceae	15	0	15	0	0	0
Mucuna species	Fabaceae	0	6	6	0	0	0
Parkia biglobosa	Fabaceae	16	0	16	0	14	14
Phyllanthus species	Euphorbiaceae	13	79	92	0	0	0
Piliostigma thonningii	Caesalpiniaceae	0	0	0	5	16	21
Pterocarpus erinaceus	Fabaceae	14	10	24	0	0	0
Sclerocarya birrea	Anacardiaceae	0	9	9	0	0	0
Tectona grandis	Verbenaceae	0	0	0	4	0	4
Terminalia species	Combretaceae	2	8	10	0	0	0
Tragia species	Euphorbiaceae	6	0	6	0	0	0
Triumpheta species	Polypodiaceae	0	6	6	0	0	0
Urena lobata	Malvaceae	18	0	18	0	0	0
Urera species 1	Urticaceae	8	0	8	0	0	0
Urera species 2	Urticaceae	4	39	43	0	0	0
Vitellaria species	Sapotaceae	0	5	5	0	0	0
Vitellaria paradoxa	Sapotaceae	0	0	0	4	15	19
Vitex doniana	Verbenaceae	0	0	0	0	13	13
Vitex species	Verbenaceae	0	7	7	0	0	0
Total		**708**	**884**	**1592**	**88**	**269**	**257**