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HAZARDS AND VULNERABILITY MAPPING FOR ADAPTATION TO CLIMATE RISKS IN SAVANNAH ECOSYSTEM: A CASE STUDY OF THE UPPER EAST REGION, GHANA

BY

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Declaration

I hereby declare that this Thesis is the result of my own research carried out in the Upper East Region of Ghana. I further declare that this document has not been submitted in part or in whole to any other institution for an award with the exception of references which have been duly acknowledged.

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Dedication

This dissertation is dedicated to my family especially lovely daughters, Geraldine Yinborim Yiran and Geralda Masong Yiran. I get the inspiration to work harder when I look at you.

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Abstract

The climate is warming, a trend that is projected to increase with increasing frequency and intensity of climate related hazards. Impacts are likely to be greater in developing countries because of dependence on climate sensitive livelihood activities. The nature and impacts of climate hazards require a study that goes beyond investigating a single hazard or livelihood activity to embrace multiple hazards and their impacts on the various livelihood activities. It is against this background that this research was set up to undertake a multi-hazard/multi-sector analysis and mapping of vulnerability and identify policy options to enhance adaptation in the savannah ecosystem, using the Upper East Region as a case study.

To achieve this, an integrated framework was developed to guide the research. Assessment of the various components of the framework required varied datasets and different methods of data collection and analysis. The primary data was collected using questionnaires, focus group discussions, photography, as well as personal observation. The secondary data consisting of daily weather and socio-economic and geographic data was collected from relevant institutions, policies and published reports. The weather data was analysed using the Standard Precipitation Index and plotted with R. The questionnaire survey and socio-economic data was analysed using Statistical Package for Social Science and Excel while the focus group discussions were subjected to manual content analysis. The datasets were used to develop indicators of exposure, sensitivity and adaptive capacity and converted into geographic layers for mapping in ArcGIS 9.3. The individual indicators were georeferenced using the district boundaries since most of these datasets were collected at district scale.

The analyses identified hazards occurring as droughts, floods, high temperatures, heavy rainfall and windstorms. They occur very frequently, sometimes alternately or concurrently. These hazards have occurred more than 9 times on the average from 1983 to 2012 and have caused considerable damage to most sectors, particularly agriculture, health, housing and water sectors. The maps produced reveal where the Region is vulnerable to these climatic hazards. Droughts/high temperatures are shown to be the most devastating hazards. The agriculture sector is the most vulnerable to droughts/high temperatures and was highly vulnerable in 9 districts, while the health and water sectors show high vulnerability in 8 and 6 districts respectively. The Region was resilient to floods/heavy rainfall with 3 and 6 districts recording low vulnerabilities in the agriculture and health sectors respectively.

Vulnerability to these hazards calls for adaptation. Analyses suggest that adaptation policies and programmes should target areas where adaptive capacity is low. Options to increase adaptive capacities and reduce vulnerability include irrigation, improving healthcare, education, extension and outreach, livelihood diversification, use of drought/heat tolerant crops and transplanting crops. Government could also consider transforming the Region's economy by partnering with the private sector to invest in available opportunities such as mining, tanning, revamping the tomato cannery, to create alternative employment, propel development and advance further research in vulnerability studies. The major contributions of this work are the multi-hazard/multi-sector approach to analysis of vulnerability and adaptation to climate risks and an integrated conceptual framework it presents.

Chapter 1 Background of the study

1.1 1.1 Introduction

The Inter-Governmental Panel on Climate Change (IPCC) has revealed that "projections of future vegetation distribution under climate change indicate that many biomes could shift substantially, including areas where ecosystems are largely undisturbed by direct human land use" (IPCC, 2014a:7).The degree of the shift is seen to increase with increasing global mean warming without a sudden threshold (Scholze *et al.*, 2006; Pereira *et al.*, 2010; Rehfeldt *et al.*, 2012, all cited in IPCC, 2014a). According to Gonzalez *et al*. (2010), the observed climate and vegetation projections indicate that one tenth to one half of global terrestrial area may be highly to very highly vulnerable to biome changes. These biome changes are likely to alter ecosystem structure and the provision of ecosystem services, affecting the livelihoods of many people (Gonzalez *et al*., 2010). One such biome (or ecosystem) likely to experience changes is the savannah ecosystem, which is supporting the livelihoods of many people, particularly in sub-Saharan Africa. The savannah ecosystem is home to a significant number of plant and animal species that provide tourism revenue, food through hunting and gathering, medicinal plants, fuel wood, construction material, cultural, regulating and supporting services (IPCC, 2014a) to both the people living in it, who depend on the system for their survival, and those situated in other areas.

The savannah ecosystem of West Africa covers the northern part of Ghana, specifically as the Guinea Ecological Zone and Sudan Savannahs, which extends from about latitudes 7° 30' N to11° N and longitudes 0° 5' E to 2° 30' W (Fig. 1.1). These ecological zones support the livelihood activities of the over 10 million inhabitants who predominantly engage in agriculture (Ghana Statistical Service, 2012a).

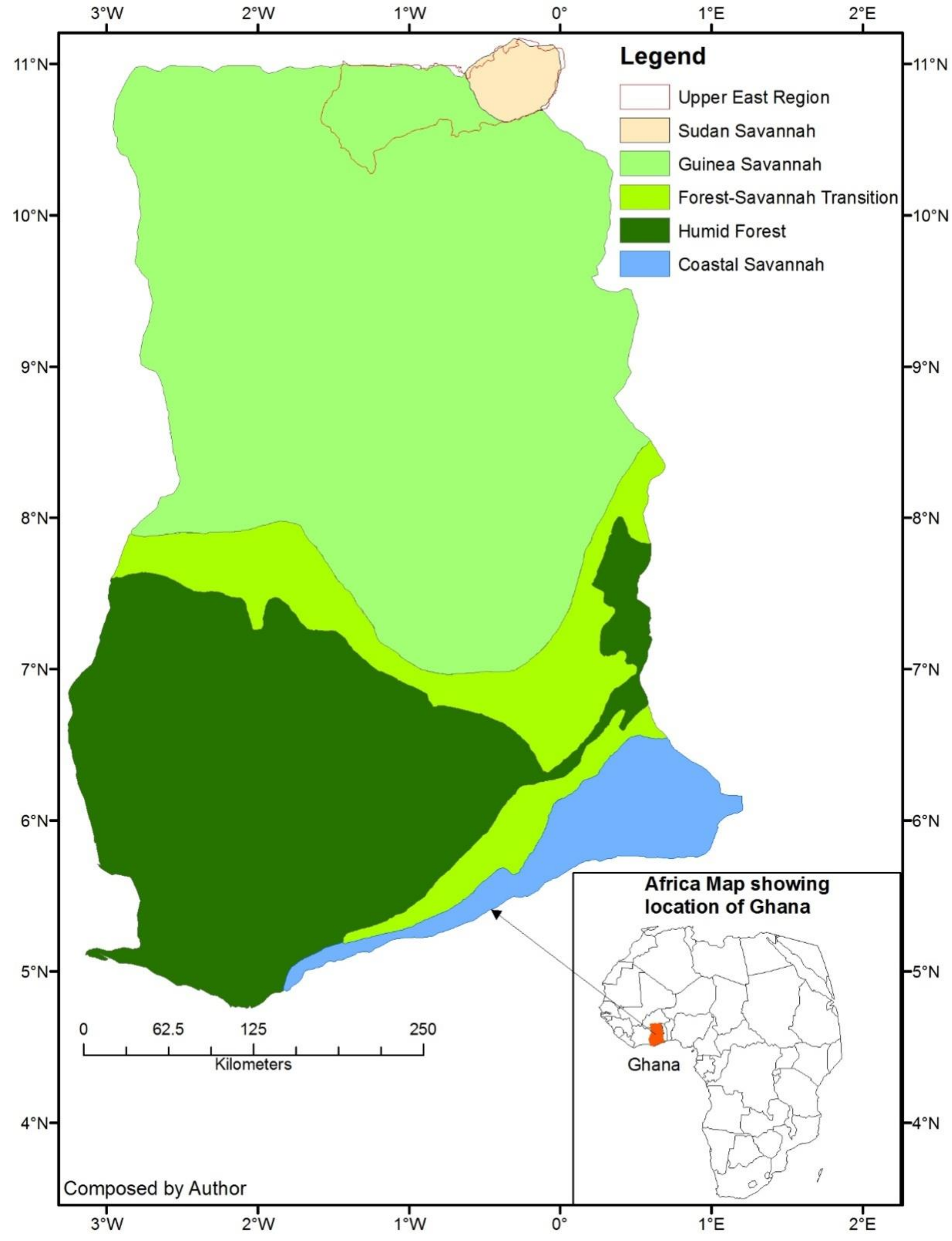

Fig. 1.1 Map of ecological zones of Ghana

The Guinea Savannah and Sudan ecological zones are considered a food basket as they produce most of the major food crops and livestock in the country (MOFA, 2010). The Guinea zones also contribute more than 54 percent of total runoff in the country into the Volta Lake, which is used largely for producing about 80 percent of the country's electricity needs (Andah *et al*., 2004; Gao and Margolies, 2009). Another important ecosystem service derived from the ecological zones is water for domestic and industrial use (Yidana *et al*., 2011). These demands are addressed (though not adequately) from both surface and ground water sources.

Socio-economic and livelihood activities in the zones are highly climate sensitive. It is often loosely said that without water, there will be no life on earth. Rainfall is the single source of water in the savannah ecosystem that feeds all other sources and supports life (Barry *et al*., 2005). The ecosystem thus depends solely on the amount and distribution of rainfall, both spatially and temporally, for its surface and groundwater recharge. The area has one peak rainy season of about 900-1200 mm of rainfall between April and October with the rest of the year being dry (Owusu and Waylen, 2009).

Agriculture in Ghana and across the interior (Guinea and Sudan) savannah is largely rainfed. Only about 0.2% of land in the country is irrigated (MOFA, 2010). Rainfall in the zone is highly variable (Fig. 1.2). It often switches from years of high rainfall to years of low rainfall, resulting in flash floods, dry spells and/or droughts. The consequence of these climate events to agriculture is often crop failure and loss of livestock (Thornton *et al*., 2008). It has been projected that rainfall will decrease by about 13% by 2080 in Ghana's Savannah region (Minia, 2004, cited in EPA, 2005). Already, there is evidence of an increasing number of dry spells, droughts, flooding and reduction in the length of the rainy season, and these have had adverse implications for agriculture (Owusu and Waylen, 2009). For example, droughts occurred in 1983/84, 1997/98, 2003, 2006/7 and affected food production in the country, leading to food shortages, especially in the north (FAO, 2009; De Pinto *et al*., 2012). Six floods also occurred in the country between 1991 and 2008 and displaced millions of people and destroyed properties and farms (The World Bank Group, 2009; BBC, 2010).

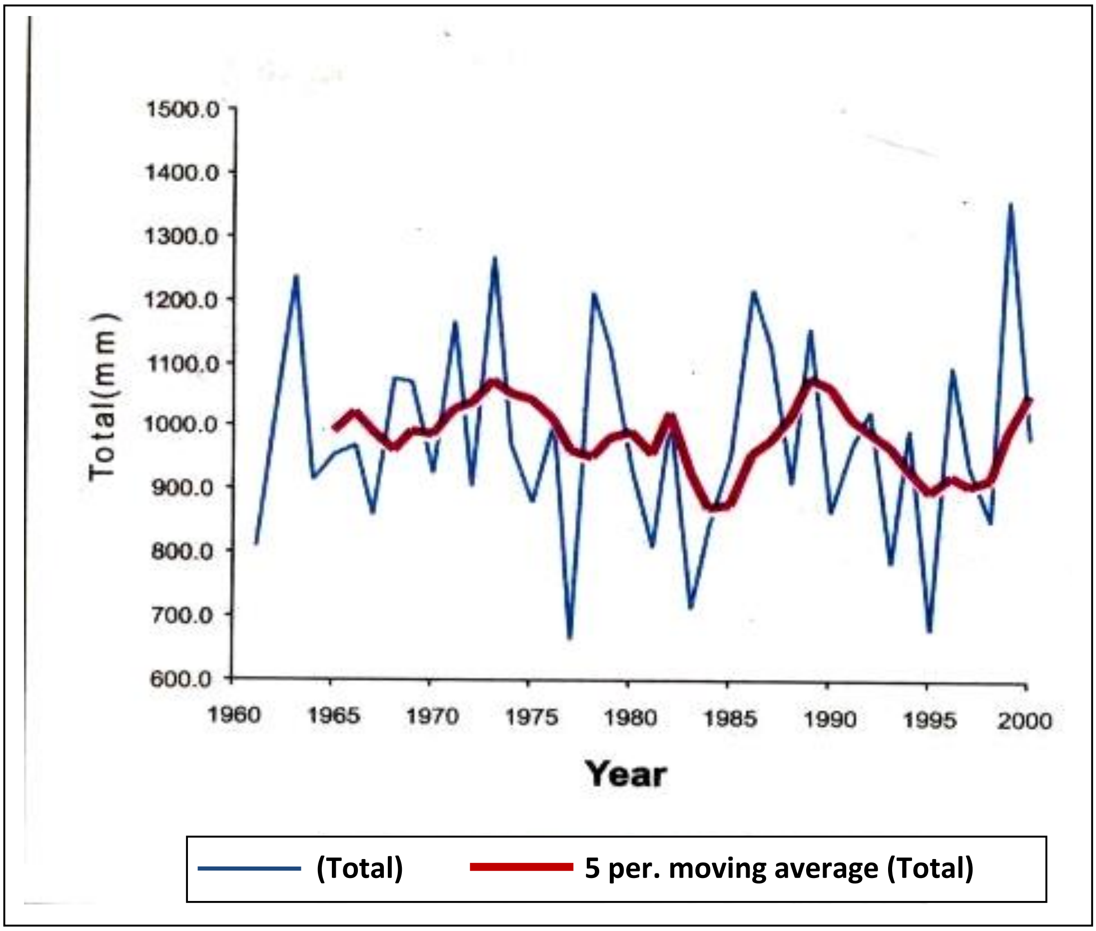

Fig. 1.2 Rainfall variability in the Guinea Savannah Ecological Zone of Ghana
Source: EPA, 2005

Apart from the high variability in rainfall, temperature is also on the rise and is projected to go up by 1°C – 3°C by 2060 and 1.5°C – 5.2°C by 2090, with greatest impacts in the north (McSweeney *et al*. (undated), cited in De Pinto *et al*.. 2012). The rising temperatures bring about high evapotranspiration, ranging between 1450mm/annum and 1968mm/annum, and annual pan evaporation of about 2540 mm (Barry *et al*., 2005). According to Oguntunde (2004), nearly 80% of rainfall is estimated to be lost to evapotranspiration during the rainy season. These high values reduce water availability in the soil for proper plant growth and surface and groundwater availability for other livelihood activities. Thus, agriculture, vegetation, and water, the main ecosystem services derived from the Savannah Ecological Zones are highly sensitive to temperature because of its influence on soil moisture content and water availability. The magnitude of these expected impacts mean that further research in this area is urgently required.

This climate sensitive ecosystem is further reported to be undergoing environmental stress from anthropogenic activities (Barry *et al*., 2005; Yiran *et al*., 2012). Studies have shown that the savannah vegetation is degrading as a result of land clearing for farming and other human activities (O'Higgins, 2007; Yiran *et al*., 2012). Studies have also shown that the soils have been heavily degraded due to exposure to agents of erosion, over-cultivation and the high intensity of heat radiation (see Senayah *et al*., 2005; Aniah *et al*., 2013). As a result of the stress experienced associated with both climate change and growing anthropogenic pressures, the economies of the Regions in the savannah zone are becoming increasingly vulnerable (Gyasi *et al*., 2006; IPCC, 2014a). Research such as that presented in this study is therefore needed in order to better understand the vulnerabilities faced.

The savannah ecosystem of Ghana has been subjected to a number of drought and flood events in recent times which may be attributed to climate variability and change (EPA, 2005; Owusu and Waylen, 2009). The frequent exposure and high sensitivity of the Region to hazards and risks make it highly vulnerable to such pressures. Vulnerability is due largely to the low adaptive capacity of the system and particularly its inhabitants, principally as a result of poverty (IPCC, 2014b). All three Regions of northern Ghana, which lie in the Guinea Savannah Ecosystem, are amongst the poorest in the country but the Upper East Region (Fig.1.1) is the most affected, and is an area in which more than 80% of its people are classified as poor (UNDP, 2012). The high poverty in the Region is due to the dependence on agriculture as the major economic and livelihood activity which in turn is climate dependent. Together with land degradation, this greatly explains the low crop/livestock production of the Region (MOFA, 2010).

It is becoming virtually an annual event that the early part of the rainy/wet season is marked by erratic and insufficient rainfall, whereas the end is characterised by heavy downpours (EPA, 2005). This highly variable rainfall pattern, coupled with high temperatures, results in dry spells, droughts and floods. These not only affect agriculture but also the health of the people, and the ecosystem's ability to provide certain services such as absorption of floods, medicine, water, construction material, etc. (IPCC, 2014a). Recent crop modelling studies suggest that agriculture in West Africa will be affected disproportionately as a result of climate change (Lobell *et al*., 2008, cited in Antwi-Agyei *et al*., 2012). This has serious implications for livelihoods, particularly for people of the Upper East Region who depend almost entirely on what is produced from the farm. The occurrence of these natural hazards (particularly floods and droughts) has also revealed the weaknesses in the disaster preparedness and emergency response systems, further exposing the people, land use and infrastructure to climate risks (The World Bank Group, 2009).

1.2 Problem statement

From the fifth assessment report of the IPCC, the savannah ecosystem is more highly sensitive to climate change and climate variability than was previously thought (IPCC, 2014a). According to Boko *et al.* (2007), "Africa's food production systems are among the world's most vulnerable because of extensive reliance on rainfed crop production, high intra- and inter-seasonal climate variability, recurrent droughts and floods that affect both crops and livestock, and persistent poverty that limits the capacity to adapt" (cited in IPCC, 2014b:9). Recent studies show that agriculture in the lower latitudes, especially in the Guinea Savannah Ecological Zone of West Africa, will be disproportionately affected by the impacts of climate change and climate related hazards (Lobell *et al*., 2008; Thornton *et al*., 2009; Thornton *et al*., 2011; IPCC, 2014b). Besides impacts on agriculture, some studies suggest that climate change among other factors will have an important effect on water scarcity (Carter and Parker 2009; MacDonald *et al*., 2009; Notter *et al*., 2012; Tshimanga and Hughes, 2012). The population at risk of increased water stress in Africa, for the full range of the Special Report on Emissions Scenarios (SRES), is projected to be 75-250 million and 350-600 million people by the 2020s and 2050s respectively (Arnell, 2004, cited in IPCC, 2007). Some studies also point to similar negative impacts on population, health and other systems in Africa (IPCC, 2014b).

Despite the negative impacts of climate change pointed out by these and many other global and regional studies, very little is known of vulnerability in the Guinea Savannah Ecological Zone, especially in the Upper East Region of Ghana, where the frequency and severity of climatic events are increasing (NADMO, 2011). The IPCC (2014b) has attributed this dearth of knowledge to lack of technical means in African countries to assess the impacts of climate change and determine effective adaptive strategies. This lack of knowledge could also be due to the complex human-environment interactions resulting in the formulation of several theories and concepts and a lack of appropriate empirical application of these concepts (Acosta-Michlik, 2005). Many studies on vulnerability have often centered on humans or society, rather than integrating human and biophysical aspects, and this has been the case for most vulnerability assessments in Ghana (Codjoe and Owusu, 2011).

Another factor that has contributed to the paucity of knowledge is that many studies have concentrated on impacts of single hazard or extreme event (e.g. flood or drought) (e.g. Antwi-

Agyei *et al*., 2012; EPA, 2012). Nonetheless, the frequent and alternate occurrence of these events, sometimes in the same rainy season, warrants a study that considers all climatic hazards to enable effective adaptive strategies to be identified and enacted. Furthermore, most studies are done at a macro-spatial (national or higher) level which does not take into account very minute spatial differences and socio-cultural settings that gradate the vulnerabilities of societies and ecosystems (e.g. Davies and Midgley, 2010). It has been stated that, studies at these macro-spatial scales do not allow realistic assessments of human responses and differential vulnerabilities to global environmental change (Acosta-Michlik 2005; Abson *et al.*, 2012). Several studies have also shown that practical initiatives that address and improve societal adaptive capacity, thereby reducing vulnerability, are commonly expected to be evident at the micro-spatial scale (Ford and Smit, 2004; Smit and Wandel, 2006). It is also at this scale that the cultural practices which have allowed societies to survive environmental stresses can be studied, such that they can inform adaptation (O'Brien and Holland, 1992, cited in Smit and Wandel, 2006).

As observed by Greiving et al. (2006), spatially oriented risk assessment must first of all be multi-hazard oriented and must go beyond sectoral considerations. A multi-hazard and multi-sector study will allow for full diagnosis of the characteristics of vulnerability and offer insights into ways of adapting to the hazards. This study targets these knowledge gaps by adopting an integrated approach to study and map the vulnerabilities of the coupled human-environment interactions to climatic hazards. To do this, it uses Geographic Information systems (GIS) at the local level. GIS offers an opportunity to integrate natural science and social science data and is therefore appropriate for this study. It is important to emphasise at this level that most of the concepts and terms used here are defined and/or discussed in chapter two.

1.3 Objectives

As shown above, the Savannah ecosystem is experiencing different hazards of different magnitudes across space and time and the socio-ecological responses also vary accordingly. This means that vulnerability (measured by the impacts and adaptive capacity) is dynamic (Abson *et al.*, 2012). It is against this background that this study aims to investigate hazard dynamics, and to map vulnerability to multi-hazards at a single snapshot in time, focusing on the savannah ecosystem using the Upper East Region as a case study. This is important in order to understand the vulnerabilities and offer policy options for adaptation in the savannah ecosystem. The aim will be achieved by:

1. Assessing the trends of climatic hazards over a 30 year period (1983-2013). In addressing this objective, answers to the following questions will be sought:
    - What are the principal hazards occurring in the savannah ecosystem?
    - What are the dynamics of the hazards over the study period?
2. Identifying adaptive/coping strategies that can be used to manage the impacts of the hazards identified in (1). The questions to be addressed under this objective will be:
    - Historically, what has been the response to these impacts in the ecological zone over the past 30 years?
    - What capacity exists to implement these measures?
3. Mapping current hazards and vulnerabilities to climate risks using GIS. This objective will be addressed by considering the following questions
    - Who and what are vulnerable to these hazards?
    - Why are these elements/groups vulnerable to the climatic hazards?

4. Examining current policies and assessing how they can be improved to further support adaptations to the climatic hazards in the savannah ecological zone.
    - What are the barriers to adaptation to the hazards?
    - What policies exist or can be formulated for adaptation?
    - How can the adaptive capacities identified be incorporated into the policies?

1.4 Structure of the thesis

This thesis is divided into 9 chapters. Chapter 1 has set out the background to the study. The problem and the objectives have been stated, as well as the research questions to be addressed. Chapter 2 reviews literature on the concepts, theories and conceptual frameworks that have been used to analyse and assess vulnerability and develops a novel framework for application in this study. In Chapter 3, the first part reviews the methodologies that have been used to analyse and map vulnerability, and profiles the study area in relation to hazards, while the second part presents the methods of data collection and analysis. Chapter 4 addresses objective 1 by analysing the data (both observed climate data and field survey) to identify hazards and their nature of occurrence. In Chapter 5, objective 2 was addressed by analysing the field survey and socio-economic data to identify the adaptive capacities present in the Region. Chapter 6 involves developing indicators of susceptibility and adaptive capacity identified in Chapters 4 and 5, and incorporates into geographic layers. Chapter 7 maps and analyses the vulnerabilities, thus addressing objective 3 by combining the layers developed in Chapter 6. Chapter 8 addresses objective 4 by reflecting on the barriers and then analysing the policy implications for adaptation to the hazards. The summary and conclusion are presented in Chapter 9.

Chapter 2 Literature Review

2.1 Introduction

The term vulnerability has been used in a number of contexts: medical science, biophysical science and more increasingly in social science (e.g. UNISDR, 2009; Cuevas, 2010; Antwi-Agyei *et al*., 2012; Abson *et al*., 2012; Cardona *et al*. 2012; Ciurean *et al*., 2013;Garbero and Muttarak, 2013). Although all these disciplines are concerned with vulnerability, their conceptualisations and approaches for assessing it are different (Brooks, 2003). For example, social scientists view vulnerability as representing the set of socio-economic factors that determine people's ability to cope with stress or change (Allen, 2003). On the other hand, climate scientists often view it in terms of the likelihood of occurrence and impacts of weather and climate related events (Stott *et al*., 2011; Christidis *et al*., 2012). In many instances, scientists from these fields and other areas such as development studies and disaster management address similar problems and processes using different languages because of their different backgrounds (Brooks, 2003). As a result, several definitions, concepts/conceptual frameworks and methodologies have been developed for vulnerability assessment and/or analysis (Hinkel, 2011). Several researchers have reviewed the different definitions (e.g. Füssel, 2009; Birkmann, 2006) given the evolving nature of concepts of hazards and vulnerability. This chapter will provide a synthesis of the main points emerging from existing reviews, introducing the concepts of hazards and vulnerability and its components; exposure, sensitivity and adaptive capacity/resilience. It will discuss different ways of systematising vulnerability and present a new conceptual framework that is relevant for the present study and which may be applied to the study of vulnerability of the savannah ecosystem and elsewhere, to climate variability and change.

2.2 The concepts of hazards and vulnerability

2.2.1 Hazards

The term hazard is usually used to denote environmental threats like earthquakes, wind, and floods, but hazards exist in all aspects of human life. Some of these may occur naturally while others may come about as a result of human actions. Recognising this, the IPCC defined a hazard as “the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage to and loss of property, infrastructure, livelihoods, service provision, and environmental resources” (IPCC, 2012:44). Hazards become disasters when physical events occur and actually cause harm to people and property. The United Nations International Strategy for Disaster Reduction (UNISDR) define a disaster as “a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope on its own resources” (UNISDR, 2009:9). That is, a disaster is the outcome of a hazard, measured in human terms (lives lost, people affected, economic losses, environmental losses) mediated by the properties of the social and environmental systems that are exposed to and affected by the hazard (UNISDR, 2009). This can be represented diagrammatically, as in Fig. 2.1.

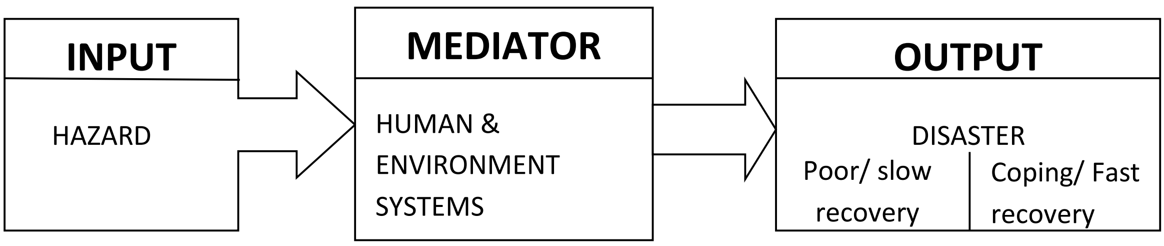

Fig. 2.1 Relationship between Hazard and Disaster
(Source: Author’s own construct)

As shown in Fig. 2.1, when a hazard becomes a disaster, in general, either the affected people become impoverished and recover slowly or they are able to cope and recover fast, though sometimes a mix of the two can occur. This way of thinking admits that disasters are socially constructed events, that is, they are products of the impact of hazards on people whose vulnerability have been created by social, economic, political and other mediating conditions (Cannon and Müller-Mahn, 2010). This makes some scholars regard vulnerability as a far greater determinant of disaster risk than the existence of hazards themselves (Ward and Shively, 2011; Hewitt, 1983, both cited in Alexander, 2006:2). Therefore, disasters caused by hazards are not only influenced by the magnitude and frequency of the hazard event but are also determined by the vulnerability of the affected society and its natural environment (Cardona *et al.*, 2012; UNISDR, 2009). It is in this light that Helmer and Hilhorst (2006) believe that the core insight that disaster studies can bring to climate-related research is that "vulnerability is critical to discerning the nature of disasters" (Helmer and Hilhorst, 2006:2).

2.2.2 Vulnerability

The everyday use of the term vulnerability refers to the inability to withstand the effects of a hostile environment but its scientific use depends on the field and purpose of the study (Ciurean *et al*., 2013). Historically, vulnerability has its roots in geography and natural hazards research (Füssel, 2006; Janssen *et al*., 2006) but has evolved to include several research contexts within the social sciences (e.g. Gassebner *et al*., 2010; Noy and Vu, 2011). From the natural hazards perspective, Blaikie *et al*. (1994) defined vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazard" (cited in Ciurean *et al*., 2013:7). Vulnerable persons or groups, referred to in this definition, are frequently classified according to their age, class, ethnicity, gender and physical or mental disability. Vulnerability however varies among different groups depending on the nature of the hazard and the socio-cultural context. The focus of the above definition of vulnerability is on the consequences of the natural hazards on society and could be considered as more socially focused (see also Malone, 2009; Lei *et al*., 2014; for more definitions of vulnerability in this field).

A more recent contribution to the literature on vulnerability comes from climate change researchers. In climate change research, vulnerability is used as an integrative measure of the probability of occurrence and impacts of the hazard (Cuevas, 2010). Much of the research on vulnerability in climate change is reflected in the numerous report of the IPCC. In the fifth assessment report of the IPCC, vulnerability is defined as "the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is therefore a function of the magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2014c:24). This definition makes the physical causes and their effects an explicit aspect of vulnerability while the social context encompasses the notions of sensitivity and adaptive capacity (IPCC, 2012). Vulnerability can also be interpreted as the residual impact of climate change after adaptation measures or adaptive capacity has been accounted for (Wilby and Miller, 2009). Therefore, vulnerability is dependent on the context and spatial scale as it reflects in the variations in wealth, social equality, availability of food, the status of health and education, infrastructure, access to natural resources and technology, which also govern the ability to adapt (Wilby and Miller, 2009).

Though the definitions of vulnerability are contextual, vulnerability can basically be put into two categories: biophysical and social vulnerability (Cutter *et al*., 2009; Clare and Weninger, 2010; Nelson *et al.*, 2010). This categorization is necessary as it will aid in eliminating or reducing the inconsistencies in the definitions (Cuevas, 2010). But there is a thin line between social and biophysical vulnerabilities: societal vulnerability to a hazard is not only the product of the physical event itself but also attributable to the prevailing social and economic system of the affected community (Clare and Weninger, 2010). Thus, depending on the complex interaction between natural events and properties of the afflicted community, natural hazards mayor may not give rise to significant disturbance in the stability of the social system (Clare and Weninger, 2010).

Biophysical vulnerability as seen by Jones and Boer (2003) is a measure of indicators such as monetary cost, human mortality, production costs, or ecosystem damage (cited in Cuevas, 2010). When viewed this way, biophysical vulnerability is focused on the traditional risk analysis of a system concerned with the probability of occurrence of a hazard and its ultimate impacts often expressed in terms of the amount of damage experienced by the exposed system (Cuevas, 2010). This is critical, especially in relation to ecosystem vulnerability as it considers the location of the exposed system and the resources available to cope (Cuevas, 2010). Social vulnerability on the other hand explicitly focuses on socio-economic and demographic factors that increase or decrease damage from hazards (Cutter *et al*., 2009). It is determined by factors such as poverty and inequality, age structure, food entitlements, ethnic composition, housing quality among others (IPCC, 2014b; Turner II, 2010). These factors should not be seen as synonymous or be equated to vulnerability but, they translate climate vagaries to human suffering and loss (Ribot, 2013).

As indicated earlier, several definitions of vulnerability exist but this research will adopt the definition given by the IPCC as outlined earlier (IPCC, 2014c). The reason for choosing this definition is that it expresses vulnerability mathematically which can be quantitatively implemented in Geographic Information Systems (GIS). It also captures the factors of both biophysical and social vulnerability in its components. The following subsections therefore reflect on these components of vulnerability (i.e. exposure, sensitivity and adaptive capacity).

2.2.2.1 Exposure

Exposure is employed to refer to the presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss, or damage (IPCC, 2012). If the elements are not located in hazard prone areas, then they will not be exposed. But as population increases, there will be increasing diverse demands for land and the gradual decrease in the availability of safer areas mean that humans and human endeavour will unavoidably be located in potentially dangerous places (IPCC, 2014c). Exposure will therefore depend on where populations choose or are forced to live and how they construct their settlements, communities and livelihoods (Brooks, 2003). Burton *et al*. (1993) take a slightly broader view of exposure, where it is the nature and degree to which a system experiences environmental or socio-political stress whose characteristics include the magnitude, frequency, duration and areal extent of the hazard (cited in Adger, 2006). This means that the intensity of some hazards is greater than others and some occur more often, faster and/or last longer than others. It further shows that areas affected by the hazard also vary depending on these characteristics and other environmental properties of the location where it occurs. Thus, it can be deduced that exposure partly encapsulates the spatial and temporal dimensions of vulnerability and makes it dynamic in both time and space (Abson *et al*., 2012).

2.2.2.2 Sensitivity

Once a system is exposed to a hazard, then it may suffer harm or damage. The degree or amount of damage the exposed system suffers is its sensitivity. According to the IPCC, sensitivity is defined as “the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)” (IPCC, 2014c:24). A key phrase in the definitions of sensitivity is “the degree to which”. This phrase is used as a measure of the severity of the climate stimuli or the amount of damage the system will (or will likely) suffer under the influence of climate stimuli. The term ‘affected or ‘modified’ in the definitions often imply negative consequences, thus sensitivity is more often than not used to connote adverse impacts.

One reason that explains the focus on adverse impacts is the fact that climate change impact assessments are more concerned with finding ways of minimising the adverse effects of climate stresses on humanity, rather than maximising new opportunities that emerge. Sensitivity of a system to climate change may depend on the innate physiological or biological variables of the system, specific physical or ecological factors and/or may be highly influenced by the presence and extent of other human-related factors (Glick *et al*., 2011). These characteristics will make the system naturally fight or resist the stimuli before yielding to them if the effects overwhelm the characteristics. This means that some systems can suffer more damage than others, even when exposed to a stimulus of the same magnitude (Simelton *et al*., 2012). For example, people who live in the tropics are more likely to withstand a heat wave than those in the Polar Regions. Similarly, flood damage will be greater in areas with mud buildings than concrete buildings. Thus, sensitivity also varies with space and time depending on the characteristics of exposure.

2.2.2.3 Adaptive capacity/resilience

The "ability of systems, humans, institutions, or other organisms to adjust to potential damages, take advantage of opportunities, or cope with the consequences" is referred to as adaptive capacity (IPCC, 2014c:2). The system is able to adapt to climate risks through its physiological or biological characteristics or through human interventions that enhance its capacity to adapt. Thus, adaptive capacity is shaped by the interaction of environmental, social, cultural, political and economic forces that determine vulnerability through exposures and sensitivities and the way the system's components internally react to the shocks (Gitz and Meybeck, 2012). It follows from the definitions that adaptive capacity is also dynamic, changing from place to place and over time in reaction to the spatio-temporal changes in exposure and sensitivity (Birkmann, *et al*., 2013; Cuevas, 2010). Adaptive capacity therefore has two dimensions: the internal reactions to shocks (coping ability or short-term adaptive capacity) and mobilisation of resources to adapt to change (management capacity or long-term adaptive capacity) (Gitz and Meybeck, 2012).

The first dimension, coping capacity, is the means by which people or organizations use available resources (both in normal times as well as during crises or adverse conditions) and abilities to face adverse consequences that could lead to a disaster (Gitz and Meybeck, 2012). Coping signifies 'here and now' capacity and includes a set of actions available to those at risk (Birkmann *et al*., 2013). According to Bermann *et al*. (2012), coping capacity can be transformed into sustainable adaptive capacity by institutions, thus enhancing adaptive capacity to future climate hazards. The second dimension goes beyond coping capacity to embraces possible adaptation measures (Levina and Tirpak, 2006). The determinants of adaptive capacity include economic wealth, technology, information and skills, infrastructure, institutions, and equity (Cuevas, 2010).

Adaptive capacity when viewed as described above applies to only social systems (Levina and Tirpak, 2006). However, its counterpart, resilience, fills the gap in the ecological system. Although the field of origin of the concept is being contested (Manyena, 2006), resilience became an important research concept following Holling's work on "Resilience and Stability of Ecological Systems", where he defined resilience as "the amount of disturbance that can be sustained by a system before a change in system control or structure occurs. It could be measured by the magnitude of disturbance that the system can tolerate and still persist" (Holling, 1973, cited in Lei *et al*., 2014:614). From the time of Holling, the concept of resilience has evolved from primarily concerning the structural balance of a system to concern system functions, including its abilities to self-organise, learn, and regenerate after a disaster (Lei *et al*., 2014). As shown in the case of adaptive capacity, resilience also has two dimensions: inherent resilience and the adaptive resilience (Zhou *et al*., 2010).

What is clear from these definitions and concepts of adaptive capacity and resilience is that they are meant to aid the system to reduce its vulnerability to hazards. Thus, some scholars consider that vulnerability and resilience are at opposite ends of a spectrum, that is, a less vulnerable system or community to a particular hazard is a more resilient community to that same hazard and vice versa, though there are still some disagreements (Adger, 2006; Renaud *et al*., 2010).Therefore, building resilience is often seen as tantamount to reducing vulnerability (Gallopin, 2006). According to the Resilience Alliance (2009), resilience is the degree to which a system can build and increase the capacity for learning and adaptation. It is therefore necessary to understand adaptation and its relationship with vulnerability.

2.2.3 Adaptation and its relationship with vulnerability to climatic hazards

Consistent in the climate change scholarship is the conceptualisation of vulnerability as a function of the exposure and sensitivity of that system to hazardous conditions and the ability or capacity, resilience of the system to cope with, adapt or recover from the effects of those conditions (Smit and Wandel, 2006). The manifestations of adaptive capacity or resilience as ways of reducing vulnerability are regarded as adaptation. Adaptation, according to IPCC, is the “process of adjustment to actual or expected climate and its effects” (IPCC, 2014c:1). The IPCC differentiates adaptation in terms of human and natural systems. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities while in natural systems, human intervention may facilitate adjustment to expected climate and its effects. Two types of adaptation are thus proposed (IPCC, 2014c:1):

i. Incremental adaptation referring to adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.
ii. Transformational adaptation which considers adaptation that changes the fundamental attributes of a system in response to climate and its effects.

Other views of adaptation exist (see Lei *et al*., 2014; McLaughlin, 2011; UNISDR, 2009) but the general idea that emerges is that adaptations are the adjustments in a system’s behaviour that reduce its vulnerability to the changing climate. As is seen in the IPCC definition and all other definitions, adaptation connotes practical actions or strategies taken by society or a system to ameliorate vulnerability to climate risk. This means that adaptation measures must be designed in such a way as to make social and ecological systems suffer little or no losses to climate related hazards. This may be achieved by understanding the spatio-temporal variations of hazards and vulnerabilities to climate risks.

2.2.4 Climate risk

Climate risk, according to Mudelsee (2010), is the probability of adverse effects from extreme values of variables in the climate system. That is, climate risk relates to extreme values of the weather or climate variables such as high precipitation, storms, floods, droughts, etc. Because climate changes, so can the various types of climate risk (floods, storms, etc.). Thus climate risks can be seen as the hazards resulting from climate variability and change. Clark *et al*. (2000) in identifying the dimensions of vulnerability as comprising exposure, sensitivity and resilience also suggest that sensitivity and exposure reasonably define risk and vulnerability by just adding resilience to risk. Following this view, it can be argued that the relationship between vulnerability and risk is linear. This argument is further strengthened by the risk-hazard model (Eakin and Luers, 2006; Füssel, 2006). However, the relationship between risk, vulnerability and resilience/adaptive capacity has been conceptualised differently in the diverse theories from the different fields of study.

2.3 Conceptual framework

Diverse theories and concepts have been used to address the complexity of vulnerability (see Miller *et al*., 2010) as there is no single theory that has fully dealt with this complex problem. This calls for a review of the theories and concepts.

2.3.1 Theoretical overview

The theoretical backgrounds shaping vulnerability research have largely come from hazard studies in the geophysical sciences, geography, human ecology, constructivism, and political ecology/economy (Eakin and Luers, 2006; McLaughlin and Dietz, 2008). These theories can be broadly grouped into four perspectives: biophysical, political ecology/economy, human ecology and constructivist perspectives (McLaughlin and Dietz, 2008). The biophysical perspective on vulnerability focuses only on the vulnerability or degradation of biophysical conditions and their direct or indirect impact on the human occupants of a landscape (see Soares *et al*., 2012). This approach conceives vulnerability as an end-point, that is, the impact of climate change after adaptation has been accounted for (Soares *et al*., 2012). This is because it generally provides an understanding of climate change impacts and informs decision-making regarding the costs of adaptation versus the costs of mitigation (O'Brien *et al*., 2007). The main focus is therefore upon the source of risk or hazard, which determines the level of vulnerability and issues such as magnitude, duration, and impact of the climatic event normally characterise this type of study. Studies using the biophysical approaches are also known as risk-hazard approaches or impact-driven studies (Eakin and Luers, 2006; Ford *et al*., 2010).

However, the narrow focus on environmental factors in this approach invariably neglects the social, economic and political factors that shape the exposure to and impacts from environmental threats (Eisenack and Stecker, 2010; Wisner *et al*., 2004, cited in McLaughlin and Dietz, 2008). It also fails to deal with the role of human agency (both individual and institutional) as well as culture in producing vulnerability, and does not consider the various livelihood and coping strategies used to mitigate or reduce vulnerability (Cutter *et al*., 2009). It therefore implies that human beings do nothing in the face of disasters. Such a view gives an impression that human agents are merely passive victims of risks of climate change (Kassam *et al*., 2011). Also, such a perspective lays more emphasis on extreme events but there are social processes that influence differential vulnerability between individuals and social groups (Cutter *et al*., 2009) and these need to be taken into account. Therefore, analyses of vulnerability will not be complete without taking into consideration, the resilience and coping strategies of humans (Kassam *et al*., 2011). Recent research has attempted to address these shortcomings with the introduction of human ecology, political economy/ecology and constructivist perspectives.

Human ecology has been defined as “the complex and varied systems of interaction between man and his living and non-living environment” (Editors, 1972, cited in Kassam *et al*., 2011:218). Some of the earliest attempts to integrate social factors into the analysis of vulnerability can be found in works on the human ecology of natural hazards (see Cutter *et al*., 2009; Kassam *et al*., 2011). The principal contribution of this concept was that it highlighted environmental variation as a causal force controlling social change and vulnerability. However, progress towards integrating the environment with the social has been limited by the persistence of essentialism (McLaughlin and Dietz, 2008). Essentialist theories conceptualise change as an interaction between natural tendencies and secondary forces that impede those tendencies. Essentialism particularly fails in practice because functionalist and developmental theorists have not been able to systematically theorise secondary interfering forces, resulting in descriptions of social change that fail to account for the diversity of actual histories (Bock, 1956, cited in McLaughlin and Dietz, 2008). These theories also fail to explain how populations maintain themselves in an ecosystem with varying cultural practices through adaptation and homeostasis (Clay and Olson, 2008).

In trying to fill in the gaps in human ecology, political economists took a much wider view than human ecologists by emphasising the sociopolitical, cultural, and economic factors that together explain differential exposure to hazards, differential impacts, and, most importantly, differential capacities to recuperate from past impacts and/or to cope and adapt to future threats (Eakin and Luers, 2006; Abson *et al*., 2012). The other major contribution political economists have made to vulnerability analysis is their constant emphasis on the role that inequality and differential political and economic power play in increasing the vulnerability of poor and marginalised groups (Pelling, 2001 and Wisner, 2003, cited in McLaughlin and Dietz, 2008). Vulnerability to food insecurity, for instance, is explained through entitlement theory as a set of linked economic and institutional factors (Adger, 2006). Important to the vulnerability discourse of the entitlements theory is its influence on coping strategies and adaptive capacity in general since the resources available to a person or society will be commanded and used in times of adversities. This is because vulnerability in the entitlement framework is the risk that a household's commodity bundles will fail to buffer them against hazards (Ribot, 2010).

Political ecology, inspired by a strong critique of the technocratic focus of traditional natural hazards researches, has been particularly influential and still has some influence on climate change and hazards research (Miller *et al*., 2010). Political ecology has its roots in structuralist and neo-Marxist thinking, providing a framework which is characterised by analyses of social and economic processes with interacting scales of causation and of social difference (Eakin and Luers, 2006). A political ecology approach aims at contextualising vulnerability at the local scale with any external or local pressures or drivers that may have an influence on, for example, food security. The strength of political ecology is that it offers researchers a way to explain external forces such as the practices of transnational corporations over local activities such as agricultural production (Bryant, 2001; cited in Khan, 2013). It also uses time series datasets to explain how vulnerability increases or decreases over time, and by this, is able to inform on the genealogy of narratives concerning the environment and identify power relationships supported by such narratives (Stott and Sullivan 2000, cited in Adams and Hutton, 2007). This justifies why the theory is essential for vulnerability studies as it focuses on the social relations that shape practice. In its sympathy with the poor and exploited, it addresses the plight of the vulnerable in terms of their abilities and constraints (Watts, 2000:164). Political ecology, moving on from a purely structuralist approach to various aspects of vulnerability, has begun to consider carefully both resilience and adaptive capacity as part of the whole schema of differential vulnerability to natural hazards, risk and environmental change.

In order to eliminate the barriers of essentialism, political ecologists have drawn upon constructivist theory (Christmann *et al*., 2014). Social constructivism is based on observation and scientific study about how people learn and create meaning of their social reality (Christmann *et al*., 2014). As human ecologists and political economists focus on the dynamics of social structure in their explanations of vulnerability, constructivists emphasise the role of human agency and culture, and view vulnerability as asocial construction process where potential threats are collectively assessed and negotiated by members of a society (Christmann and Ibert, 2012). This theory sees vulnerability as a collectively selected entity (that is valuable and to be preserved), delimited and located at the centre of an actor-network (with its inherent social, immaterial, material, and/or spatial structure) at a certain point in time (Christmann *et al*., 2014). Actors, according to Snow *et al*. (1986), interpret their experiences in relation to ''frames'' which provide '''schemata of interpretation' that enable individuals 'to locate, perceive, identify, and label' occurrences within their life space and the world at large'' (cited in McLaughlin and Dietz, 2008:102). This is very important because people or communities identifying certain occurrences within their environments as hazards depend largely on their perception. In turn, people's perceptions affect whether they adapt or not.

Constructivist perspectives have helped fill the lacunae within both the human ecology and political economy perspectives by providing insights such as transforming our understanding of the role played by culture and agency in producing differential vulnerability within society; disaster victims are not merely victims but also survivors and active agents, while vulnerability researchers are an integral part of the everyday social interactions that could contribute to, or mitigate, vulnerability (McLaughlin and Dietz, 2008). However, constructivists have been critiqued for failing to adequately theorise the dynamics of social structure which can be traced to the persistence of nominalism within the constructivist tradition (McLaughlin, 2001, cited in McLaughlin and Dietz, 2008). Realising this, constructivists shifted from what they called radical constructivism to moderate constructivism which conceptualises social categories as bounded networks with increased interest in the dynamics of social boundaries (e.g. Lamont and Bail, 2008; O'Flynn, 2014).

It is obvious from the discourse provided in this chapter that no single theory is able to adequately address the issue of vulnerability. Thus, there is an increasing cross-fertilisation and convergence of theoretical perspectives. In this regard advocates of political ecology have demonstrated a lead role by attempting to synthesise the conceptualisations of a number of theoretical perspectives (McLaughlin and Dietz, 2008). As stated by McLaughlin and Dietz (2008), "a comprehensive theory of vulnerability must be capable of addressing the interrelated dynamics of social structure, human agency and environment(s)" (McLaughlin and Dietz, 2008:104). As such, this research will be driven by a strong consideration of these factors especially at the local level, where the interplay of these factors are important in determining vulnerability.

2.3.2 The conceptual framework

Some of the conceptual frameworks express vulnerability in terms of exposure to a hazard, the sensitivity of the exposed system, the resilience/adaptive capacity of the system and the possible adaptations. For example, Bohle's (2001, cited in Ciurean *et al*., 2013) double structure of vulnerability views vulnerability as having an external and internal side. The external side is related to the exposure to risks and shocks while the internal side, also called coping, relates to the capacity to anticipate, cope with, resist and recover from the impact of a hazard (Ciurean *et al*., 2013). The pressure and release model developed by Blaikie *et al* (1994) also views vulnerability in relation to risk and hazard (cited in Cutter *et al*., 2009). This framework works at different spatial, functional and temporal scales and takes into account the interaction of multiple perturbations and stresses/stressors (Ciurean *et al*., 2013). It conceptualises vulnerability at three progressive levels: 1) the root causes (e.g. limited access to power, structures or resources or political ideologies or economic systems); 2) dynamic pressures such as demographic or social changes in time and space (e.g. rapid population growth, rapid urbanisation, lack of local institutions, appropriate skills or training) and 3) unsafe conditions posed by the physical environment (e.g. unprotected buildings and infrastructure, dangerous slopes) or socio-economic context (e.g. lack of local institutions, prevalence of endemic diseases) (Ciurean *et al*., 2013).

Another framework worth mentioning here is the sustainable livelihood framework. The sustainable livelihood framework examines the vulnerability context in which people are living, their livelihoods assets and the transforming structures and processes that generate livelihood strategies leading to livelihood outcomes (Birkmann, 2006). Important here are the five livelihood asset categories and transforming structures and processes that shape poverty which is considered as one of the reasons for low adaptive capacity (IPCC, 2012). For a review of the conceptual frameworks, see Birkmann (2006) and Ciurean *et al*. (2013).Though the conceptual frameworks enhance our understanding of vulnerability, only some of them result in paradigms of quantitative or qualitative vulnerability assessment (Ciurean *et al*., 2013). Those that result in quantitative or qualitative vulnerability assessment will be integrated and used for assessing and mapping vulnerability in the savannah ecosystem in the present research.

In this regard, the framework (Fig. 2.2) designed here integrates the double structure of vulnerability, the sustainable livelihood framework, the Pressure and Release (PAR) model and the global environment change framework, while the overarching premise that guides the study is that of the IPCC, which defines vulnerability as a function of exposure, sensitivity and adaptive capacity (IPCC, 2014b).

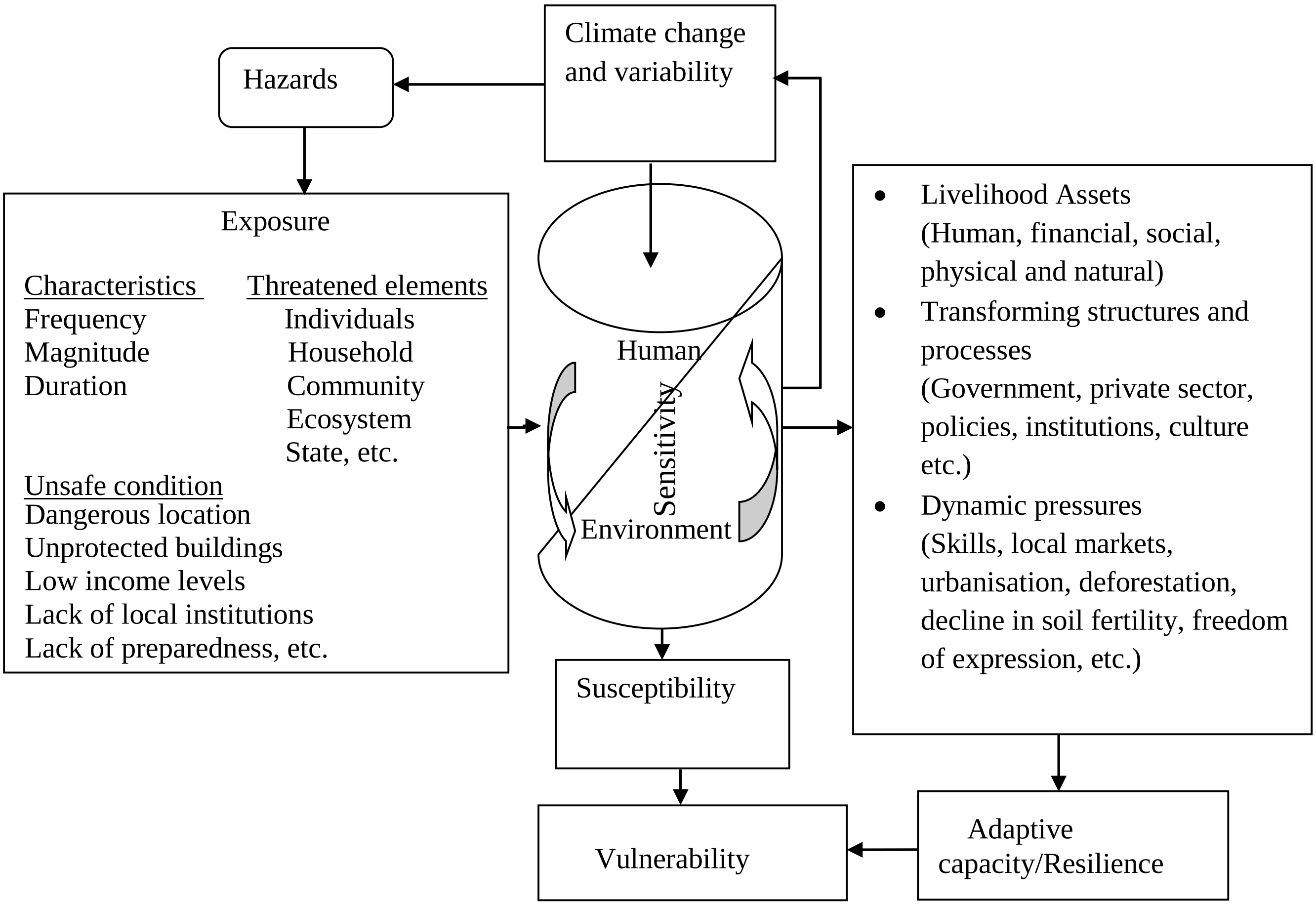

Fig. 2.2 An integrated conceptual framework for vulnerability assessment and mapping
Source: Author's own construct

Thus, the essential parts of the other frameworks that help in the identification and quantification of indicators are brought into play under the components of vulnerability defined by IPCC and used to construct the framework. In the framework (Fig. 2.2), the coupled human-environment system is perceived as a container which is receiving, producing and moderating the drivers of the climate system. It is from this human-environment system that the greenhouse gases which cause climate variability and change are emitted (IPCC, 2012). Climate variability and change also manifests itself in the form of hazards to which the human-environment system is exposed. Exposure can be expressed in terms of components (i.e. threatened systems) and its characteristics and is explained by the biophysical, political economy and entitlements theories (Ciurean *et al.*, 2013). Within the debate of social vulnerability, the term exposure also deals with social and institutional features, meaning "processes that increase defenselessness and lead to greater danger, such as exclusion from social networks" (Birkmann, 2006:19). These could be linked to unsafe conditions in the PAR model (Birkmann, 2006). The degree to which the human-environment system (i.e. the exposed system) yields to these hazards by suffering damage, loss of property and entitlements, or even loss of life, is related to the sensitivity of the system and is also explained by the biophysical, political economy and entitlements theories. The combined effect of exposure and sensitivity according the IPCC (2014b) is the potential impact or susceptibility of the system to climate change.

However, within the coupled human-environment system are a set of social and environmental assets which humans use in order to mitigate or minimise these susceptibilities and sustain their lives (DFID, 1999, cited in Birkmann, 2006). Thus, borrowing from the sustainable livelihood approach are the five livelihoods assets (human, financial, physical, natural and social) and the transforming structures and processes (levels of government, private sector, culture, laws, policies) that influence livelihood strategies and their outcomes (Birkmann, 2006). Central to the sustainable livelihood approach, which is essential for this work, is that it views people and communities on the basis of their daily needs, acknowledging the various capabilities the poor and marginalised people can offer (de Haan and Zoomers, 2005).

The daily needs of people and communities guide their activities which may increase or decrease their susceptibility to hazards. The use of these livelihood capitals and transforming structures and processes could result in dynamic pressure (see PAR in Birkmann, 2006) such as demographic and social change over time and space which bears on the coping or adaptive capacity of the human-environment systems. However, the sustainable use of the livelihood assets and structures and processes will lead to positive dynamic pressures which will enhance the adaptive/coping capacity of the system. The human-environment system and its interactions may also be able to adjust itself to withstand or transform to a state that it suffers very little or no damage from the hazards. The residual impact after adaptive capacity has been accounted for when a sensitive system is exposed to a hazard, taken from IPCC's (2014b) definition, is vulnerability. Thus, with increased coping/adaptive capacity, the vulnerability of the human-environment system will be greatly reduced if not eliminated. Inherent in the framework is that vulnerability is dynamic over space and time (Birkmann, *et al*., 2013; Cuevas, 2010).

The framework (Fig. 2.2) brings together several frameworks and their theoretical underpinnings into a single model and therefore takes advantage of the strengths of these frameworks to quantitatively and qualitatively assess and measure vulnerability. As noted by Ciurean *et al*. (2013), there is no general model that can satisfy all needs, thus, this framework is by no means assumed to satisfy all needs. Rather, it is an attempt to capture most of the variables that can be used to measure and map vulnerability. Recognising these variables are dynamic, this then paves the way for a methodology to be designed to capture the variables mentioned in the framework for vulnerability analysis and mapping, even though the maps produced are acknowledged to reflect a particular snapshot in time.

Chapter 3 Research Design and Methodology

3.1 Introduction

As stated in Chapter 2, there are several methods for assessing and measuring hazards and vulnerability. Each of these methods has its strengths and weaknesses. The objective of this chapter is to take a look at these methods and the study area, and choose those methods that can best be applied to the current investigation in relation to the study area. Thus, the chapter begins with a discussion of the methodological approaches for assessing and mapping hazards and vulnerability and a description of the study area. It then presents the methods that were used to collect and analyse data for the present study.

3.2 Methodological review

3.2.1 Vulnerability Assessments

Vulnerability assessments require a step by step approach using tools that are essential to collect credible, significant, and valid information (Cash *et al*., 2003, cited in Polsky *et al*., 2003). Some scholars have devised seven steps, and others, eight steps for carrying out hazard and vulnerability assessments (e.g. Polsky *et al*., 2003). Each of the steps might require different kinds of tools to execute. However, the selection of method(s) depends upon the availability of resources, models, and data. In data scarce areas such as the Upper East Region, it will be more prudent to collect data at the local level as well as use tools that generate data at higher spatial levels and disaggregate to lower levels to supplement. These approaches to vulnerability assessments have been described as two alternative but complementary approaches to impact assessment and can be summarised as (IPCC-TGICA, 2007):

1. A top-down approach involving the interpretation and downscaling of global-scale scenarios to regional level and

2. A bottom-up approach that builds scenarios by aggregating from the local to regional scales.

The first approach relies heavily on the use of scenarios but the resolutions of these scenarios are too coarse for studies of this nature. The advancement in technology and refinement of models has led to the introduction of regional models. However, credible assessment at the community level requires projections of community development to be compatible with ongoing and prospective trends. This means that at the local level, historical data and information about ongoing trends as well as qualitative and other information from local resource managers, decision makers and NGOs, is of great importance, so as to obtain credible scenarios at the local and regional scale (IPCC-TGICA, 2007).

Analysis of observed data combined with downscaled climate data will provide information on the hazards prevailing in the area over the past, present and the future. Information about the level of exposure and sensitivity inherent in the coupled human-environment system (Fig. 2.2 in chapter 2) is best collected at the local level as the characteristics are generally system dependent and manifest more at the local level. Similarly, extracting information on adaptive capacity also requires a blend of local and the higher level techniques at different spatial levels. Whilst a detailed description of the tools chosen and data processing procedures for gathering data pertinent to this study are discussed later, the above review suggests that local level assessments such as this should rely more on the bottom-up approach with the downscaled information providing a framework for scenario building. The information gathered at this level is very useful for deriving metrics for vulnerability mapping.

3.2.2 Vulnerability measurement and mapping

Vulnerability is a complex and difficult concept to measure. It is often more difficult to define criteria for quantifying vulnerability because it is not a directly observable event (Downing *et al*., 2001). Thus decisions about which systems or geographical locations are more vulnerable than others would most likely find acceptance if based on agreed criteria that are transparent, robust and objective (Adger *et al*., 2004). In supporting this thesis, Luers *et al*. (2003) catalogued a number of scenarios that make it difficult to identify which system is more vulnerable without some defined criteria on which to base the comparison (Luers *et al*., 2003:256). Notwithstanding the complexities as expounded in the literature, the assessment of vulnerability requires a reduction of potentially available data to a set of important indicators and criteria that facilitate an estimation of vulnerability (Damm, 2010). The need to develop systems of indicators of disaster risk and vulnerability at national and sub-national scales that will enable decision-makers to assess the impact of disasters was emphasised in the Hyogo Framework for Action 2005-2015 (UNISDR, 2005) developed after the World Conference on Disaster Reduction.

Several definitions of indicators exist in the literature (e.g. Damm, 2010; Moldan and Dahl 2007; Birkmann *et al*. 2006; Nardo *et al*. 2005). This research adopts the definition given by Hammond *et al*. (1995) who defined indicators as “quantifiable constructs that provide information either on matters of wider significance than that which is actually measured, or on a process or trend that otherwise might not be apparent” (cited in Vincent, 2004:6). Indicators are not measured directly but are composed from data (primary and/or secondary; quantitative and/or qualitative) with the quality of data used to compose indicators determining their quality. For example, poverty is an indicator calculated from the use of economic variables such as income, consumption, assets, dependency ratio, etc. by statistical means to indicate the standard of living in a particular country or locality. Indicators can be aggregated into composite indicators by the use of mathematical relationships and weights. Composite indicators are valued for their ability to integrate large amounts of information, ideally producing a more comprehensive model of reality (Vincent, 2004). Weights can be generated through methods such principal component analysis, factor analysis, expert judgement or Delphi exercises, among others.

The strength of indicators is that they summarise the complex reality in simple terms useful for decision making and for comparison and monitoring, across space and time. This is particularly useful for vulnerability studies as vulnerability varies across space and time. However, their biggest weakness is that the multi-facets of reality are difficult to encapsulate in an indicator. This means that the more complex the reality and the more intangibles the indicator is trying to summarise, the greater the danger that the indicator will not represent reality accurately (Vincent, 2004). It is also difficult to verify indicators in the field because they are summaries and capture intangible processes as well, and these, together with aggregating them further, distort reality and open them up to subjectivity. This calls for a critical appraisal of the usefulness and limitations of indicators by allowing a continual process of refinement of the results so that indicators can be valid and useful for policy (Vincent, 2004).

The selection and/or creation of indicators at all levels include methodological issues concerning fundamental choices between data-driven or theory-driven approaches (Niemeyer, 2002, cited in Bisaro *et al*., 2012). According to UNEP (2001), the data-driven (also called inductive) approach has the possibility of choosing from a large number of potential vulnerability indicators in what is termed the 'vacuum cleaner' approach (cited in Bisaro *et al*., 2012). From this selected pool of indicators, the final set is then selected by expert judgements or principal component analysis (e.g. Nardo *et al*., 2005). The weakness inherent in this inductive approach is that a proxy variable must be set as a benchmark that can be used to test all indicators, but in reality, this is somehow non-existent as there is no such tangible element of vulnerability (Vincent, 2004). The theory-driven (also called deductive) approach makes use of existing theoretical insights into the nature and causes of vulnerability to select variables for determining the indicators, however, within the limits of data availability (Briguglio, 1995, cited in Bisaro *et al*., 2012). This also has the weakness of being subjective in the selection of indicators but the subjectivity can be reduced by making sure that all decisions made are based on existing literature and are as transparent as possible (Vincent, 2004). Thus, the deductive approach will be used in this research, especially because the research is conducted in a data scarce environment and is a cross-sectional study. This then calls for a review of the study area so as to provide the basis for the choice of tools and indicators for quantifying and mapping vulnerability.

3.3 The study area

Although the study is concerned with the Guinea Savannah Ecosystem, a small case study area (Upper East Region) was selected to allow detailed local level analysis of hazards and vulnerability as it is acknowledged in other studies that vulnerability is a spatial problem (Vogel and O'Brien, 2004) and varies even at the local level. Therefore, local level analysis will more appropriately diagnose the problem and offer suggestions for reducing the impacts. The Upper East Region of Ghana was selected because it experiences nearly all the climatic hazards occurring in the savannah ecosystem (NADMO, 2011) and as such offers a good test case study. The Region has diverse natural features and human activities that shape the nature of the environment and ecosystem. This means that the Region could be viewed with several lenses. For the purpose of this study, the profiling will be done in terms of the biophysical and socioeconomic components which govern vulnerabilities to hazards.

3.3.1 Biophysical characteristics of the Region

The natural environment is composed of the hydrology, geology, soils and vegetation which are shaped by the prevailing climatic conditions and modified by human activities. These are broadly categorised into location, topography and drainage system, geology/soils, vegetation and climatic conditions, which collectively influence and shape the savannah ecosystem.

3.3.1.1 Location, topography and drainage system

The Upper East Region (UER) is located between Latitudes 10° 16’N and 11° 00’N and Longitudes 0° 02’E and 1° 33’W (Fig. 3.1) with an area of about 8,842km^2 representing less than 4% of the total land mass of Ghana (Ghana Statistical Service, 2012a). As shown in Fig. 3.1, the Region is bounded to the north by Burkina Faso, to the west by the Upper West Region (of Ghana), to the east by Togo and to the south by the Northern Region (of Ghana). The topography is generally gently sloping and can be described as rolling land, with slopes ranging from 1 to 5 percent with some isolated rock outcrops. At the south-eastern border lays the Gambaga escarpment, as evidenced by the spread of the contours (Fig. 3.1).

Due to the gentle nature of the topography, the Region has few rivers with a large network of streams which only contain water in the rainy season and dry out completely in the long dry season.

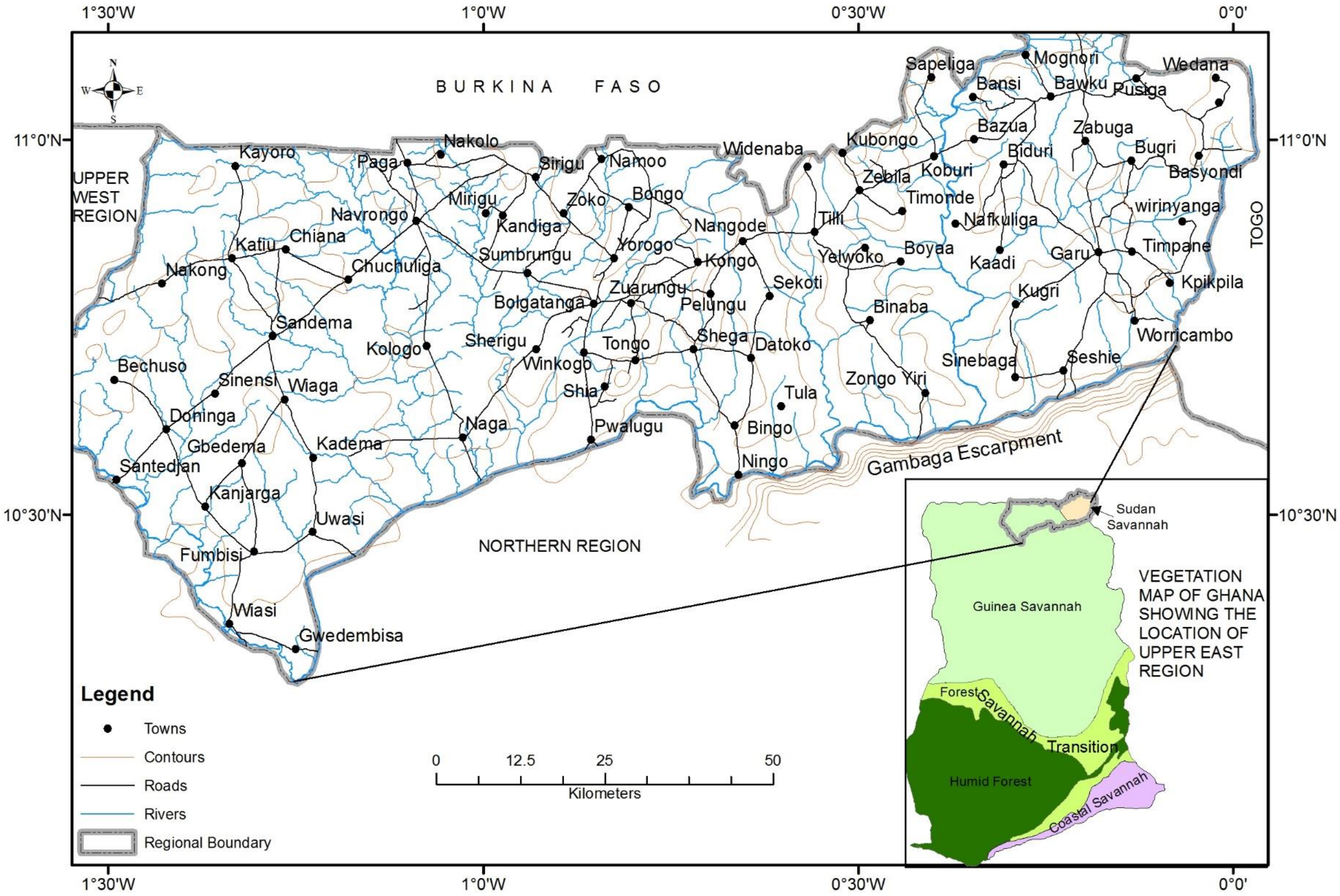

Fig. 3.1 Map of the Study Area Composed by Based on

These rivers and streams (see Fig. 3.1) channel runoff downstream and areas around their banks are usually flooded during the period of heavy downpours and during the opening of the Bagre Dam in Burkina Faso (IESS, 2012). The siltation these water courses has resulted in some courses being used for human activities such as farming and housing, exposing the inhabitants and crops to floods. There are dams and dugouts constructed to store some of the runoff for both domestic and agricultural use. The Region has more than 200 of such dams and dugouts (GIDA, 2013). These impoundments also help recharge the aquifers, from which groundwater is harnessed through wells and boreholes largely for domestic use and to a small extent, for irrigation of vegetables (Namara *et al*., 2011).

3.3.1.2 Geology and soils

Soils in the Region have low organic matter content due to rapid decomposition, overgrazing and bush burning and are dry in the surface horizons (Adu, 1969, cited in Yiran, 2008). The low organic matter content coupled with the continuous disturbance of the soils weakens the soil structure and makes the soils susceptible to erosion and leaching. It has been estimated that the thickness of the topsoil in the Sudan savannah zone decreased from a range of 35-75cm to 20-45cm between 1969 and 1993, representing a loss of over 35percent due to erosion (Senayah *et al*., 2005). Most of the soils are also exposed to the vagaries of the weather after harvest or land preparation resulting in high evapotranspiration, erosion and leaching (Liebe *et al*., undated). These together with continuous cultivation result in low fertility of the soils, hence the soils are less productive agriculturally.

Sheet, gully and rill erosions are common in the Region but sheet erosion is the most prevalent as the farming landscape is usually exposed after harvesting and the topography is nearly flat (Halm and Asiamah, 1984; Yiran *et al*., 2012). It is therefore not surprising that most of the soils have shallow profiles containing iron pans and gravels, with the texture varying from coarse sand to clay (Fenning *et al*., 2010). Some of the soils also become easily saturated and waterlogged, flooding the area and carrying some soils and organic materials along (Yiran *et al*. 2012). Also lateritic concretions underlay the top soil and these reduce water percolation, thereby increasing runoff (IESS, 2012). The eroded materials find their way into the water bodies/courses, silting them up, and reducing the capacity of these water courses to contain runoff and buffer floods. Some of these silted water courses and flood prone areas have been used for residential facilities, especially in the urban areas where the need for land for such uses is high, thereby blocking the free flow of water when it rains and causing flooding in some areas. The nature of the soils thus makes most of the population's livelihood activities (especially agriculture) vulnerable to droughts/floods.

The geology on which these soils are formed also contains some precious minerals giving rise to small scale gold and illegal mining activities, locally called '*galamsay*' (Tom-Dery *et al*., 2012). These uncontrolled mining activities coupled with other human activities such as farming, grazing and bush burning have untold effects on the vegetation resulting in pollution and land degradation especially in this fragile savannah ecosystem (O'Higgins, 2007).

3.3.1.3 Climate and vegetation

The climate of the Region can be described as dry sub-humid with average annual rainfall of 956 mm and a range of 682–1310 mm (Webber, 1996a, cited in Blench, 2006). The Region has one rainy or wet season and one dry season in a year. In recent times, the dry season seems to be longer than the wet season due to the late start of the rains and in some cases, their early termination (Logah *et al*., 2013). Much of the climate in the Region is influenced by the movement of the Inter Tropical Convergence Zone (ITCZ) (Conway, 2008). The ITCZ is a zone of low pressure around the Equator where two trade winds; the southeast trade winds and the northeast trade winds blowing from the southern and northern hemispheres respectively, converge (Conway, 2008). The convergence of these winds produces intense convection, clouds and precipitation (Scott, 2013).

The ITCZ remains near the Equator over the sea but moves north and south over land in unison with the seasonal tilt of the globe towards the sun (Conway, 2008). This oscillation in its location results in the alternation of wet and dry seasons in the tropics, thereby producing one wet season in a year in the Guinea and Sudan savannahs of the UER during the northern summer when the ITCZ is moving northward (UNECA, 2011). The north-south movement of the ITCZ affects rainfall in the Guinea and Sudan savannahs of Western Africa. When the ITCZ does not migrate as far north as usual, droughts can occur in the Sahel of Africa and affect the Guinea and Sudan savannahs. On the other hand, when it migrates further north than usual, heavy rains and floods occur in the Sahel with similar or even higher impacts on the Guinea and Sudan savannahs (UNECA, 2011). The heavy rains and resultant flooding create pools of water that breed mosquitoes, leading to high incidences of malaria (Ghana Health Service, 2012).

As the Region falls within the tropics, air temperatures are relatively high throughout the year. The temperature ranges from as low as 15°C (night time) between November and January when the cold dusty Harmattan (northeast trade) winds prevail in the Region to as high as 40°C (day time) between March and May when the sun is over-head with less cloud cover (EPA, 2005). Temperatures remain high until the influence of the monsoon is maximum, pushing the ITCZ to the north and bringing cloud activity and rains to the area and thereby lowering the temperatures (Conway, 2008). The Region lies within the meningitis belt of Africa and therefore high temperatures pose a threat to the health of the people because the high incidence of CSM during the hot period (Obiakor, 2013). Potential evapotranspiration is very high during the long dry season between November and April when the daily temperatures are high and relative humidity is low in the area (EPA, 2005). The evapotranspiration has an influence on the water cycle in the area, especially surface water resulting in water scarcity and water management problems in some areas.

Although the location and character of the ITCZ are controlled by several features of the general atmospheric circulation, local processes such as the tropical convection and the alternation of the monsoon determine the regional and seasonal patterns of rainfall and temperature which could also be remotely influenced by the El Niño-Southern Oscillation (ENSO) of the Pacific Ocean (UNECA, 2011). The changes in precipitation, temperature, and other environmental variables related to ENSO have effects such as drought, flood, changes in transmission and outbreaks of infectious diseases and other extreme weather events, impacting on human life as well as economic activities (IPCC, 2014b).

The vegetation of Ghana is divided along climatic zones with the savannah ecosystem falling in dry sub-humid or semi-arid climate (Owusu and Waylen, 2009). The savannah ecosystem (grassland) in Ghana comprises largely the Guinea savannah with the Sudan savannah occupying a small area (Zebilla-Bawku-Pusiga) (see inset map of Fig. 3.1). Grassland vegetation has been degraded due to farming, firewood and charcoal burning, overgrazing, bushfires, erratic and unreliable rainfall and in recent times, surface mining/*galamsay* (Senayah *et al*., 2005; Tom-Dery *et al*., 2012; O'Higgins, 2007). The degradation has resulted in inadequate quality grass and rafters for thatch and pasture for grazing, reduced tree density and scarcity of firewood.

3.3.2 Socio-economic background of the Upper East Region

3.3.2.1 Social and cultural characteristics

The Region has many ethnic groups from within Ghana and beyond. It is however, divided along the major ethnic groups into 13 administrative districts namely Bolgatanga and Bawku Central Municipal Assemblies, Binduri, Bawku West, Bongo, Builsa North and South, Garu-Tempane, Kassena-Nankana East and West, Nabdam, Pusiga and Talensi District Assemblies. Bawku Central, Bawku West, Binduri, Garu-Temapne and Pusiga Districts are indigenous districts for the Kusasis, Mamprusis, Moshis and Bosangas while the Frafras are in Bolgatanga and Bongo Districts. The rest of the districts are named after their majority/indigenous tribe or ethnic group.

The family is the most trusted social unit and builds into kinship, clans, sections, communities and ethnic groups. The system of inheritance, kinship affiliation and social identity of the family in the Region is patrilineal (Whitehead, 2004).The extended family/kinship support system is declining due to economic hardship and modernisation and this breaks down the traditional fallback mechanisms (Government of Ghana *et al*., 2011). Thus, people in the dependency category, particularly children, orphans, the elderly, widows and the disabled, are increasingly being denied support and this has negative implications for adaptation to hazards. Land acquisition is largely by patrilineal inheritance and this has led to the land being extensively fragmented. This kind of inheritance has contributed to an increase in the number of smallholder farmers. Farming has also remained largely at subsistence level because of the large proportion of smallholder farmers, and as a result this sector has received low investment (MOFA, 2009). Cultural practices such as land preparation for farming and bush burning for festivals, hunting and honey extraction expose the soil to erosion and have led to the degradation of the ecosystem with negative implication on livelihoods (O'Higgins, 2007). These activities and circumstances reduce the ability of the people to adapt or cope with hazards.

Virtually the entire landscape of the Region is under human use as the traditional shifting cultivation and bush fallowing systems of farming have given way to a more sedentary and continuous farming (Gyasi *et al*., 2006). Mixed farming is generally practiced and the crops are mostly intercropped while livestock are kept under varying degrees of confinement and free range. Crops produced are largely cereals such as millet, sorghum, maize and rice. Crop diversification has been shown to increase the resilience of farmers to climate change in sub-Saharan Africa (IPCC, 2014b). The livestock population puts pressure on the limited rangelands, resulting in overgrazing. Besides farming, the people also practice gathering and collection, especially of sheanuts, *dawadawa* and honey from the wild. These practices generate additional income to support household needs and adaptation to hazards.

3.3.2.2 Population and settlement

The population of the Region stood at 1,046,545 representing 4.2 percent of Ghana's total population in 2010 (Ghana Statistical Service, 2012a). As the population continues to grow, there will be more pressure on an already over stressed ecosystem to provide food, shelter and other services. The quest to satisfy these demands may push people, especially the poor in the towns, to live in unsuitable and deplorable areas, leading to increasing vulnerability to hazards (Oteng-Ababio, 2011; UN-Habitat 2009). About 80 percent of the population live in rural areas where the settlements are dispersed, making delivery of some services (e.g. electricity, water, emergency services) both difficult and expensive (Blench, 2006). Majority (81%) of the houses are built with mud bricks/earth and roofed with thatch or mud/earth and metal sheets and the mud/earth buildings more often collapse when it rains heavily (SADA, 2010) and the roofs are also ripped off by the intense winds which normally precede the rains (Yiran *et al*., 2012). The increasing incidence of these climate related events repeatedly destroys properties, requiring time and resources to reconstruct, and hence, increasing poverty.

3.3.2.3 Energy, education and other infrastructure

The energy supply and coverage in the Region is poor as only about 24 percent of the dwellings have access to electricity with close to 96 percent of the supply concentrated in the towns (Lighting Africa, 2012). Biofuels such as wood, charcoal, millet/sorghum stocks and cow dung are used for cooking. The dependence on wood products for energy contributes to the reduction in tree density and opens the area up to the impact of hazards such as windstorms and heat (high temperatures), increased runoff and other forms of degradation such as erosion and possibly desertification (Senayah *et al*., 2005; O'Higgins, 2007). The transport sector is equally poorly developed. The major roads such as the Bolgatanga-Tamale, Bolgatanga-Bawku, Bolgatanga-Navrongo-Paga and Navrong-Sandema roads and some few roads in these towns are tarred; the rest are feeder roads. Thus, in the rainy season, most of the roads are eroded while some bridges collapse or are washed away, making the roads unmotorable (Buys *et al*., 2006). The UER has poor educational infrastructure and high illiteracy level which affect people's ability to engage in other livelihood activities than farming due to low level of skills and hence increases their vulnerabilities (IPCC, 2014b).

3.3.2.4 Economic activities and governance

The main economic activity of the people in the Region is agriculture employing more than 60% of the labour force (Ghana Statistical Service, 2012a). Agriculture is still largely rainfed with less than 0.2 percent of Ghana's agriculture being irrigated (Namara *et al*., 2011). The main irrigation projects are the Tono and Vea irrigation projects but there are over 200 small dams/dugouts that have been constructed in the Region for dry season gardening and watering of animals. These are managed by households or communities (GIDA, 2013). This has left agricultural production at the mercy of the weather, more frequently resulting in production losses (MOFA, 2009). Other economic activities that employ a significant number of people include formal employment, small-scale mining/*galamsay*, quarrying, construction, weaving (local wax for smock, basketry, mat making, hat making, etc.), pottery, black smith, brewing, shea butter processing, leather works, etc. (Ghana Statistical Service, 2012a). Migration could also been seen as an economic activity since some of the people migrate to the southern part of country during the dry season to look for temporary jobs and return in the wet season to farm. Those who settle permanently in their new areas also keep ties with their relatives back home through remittances in the form of cash or goods (Castaldo *et al*., 2012; Addai, 2011) and all these contribute to household income and increase capacity to adapt.

The institutions present in the Region are the government institutions, Non-Governmental Organisations (NGOs) and development partners. The government institutions are made up of the local government system (headed at the regional level by the Regional Coordinating Council (RCC) and at the local level by the District Assemblies), District Agricultural Development Units (DADU, formerly of MOFA), District Directorate of Health Services, Ghana Education Service (GES), National Disaster Management Organisation (NADMO) among others which provide services to the communities within their jurisdiction. Although all these institutions and agencies are there working for the betterment of the lives of the people, the situation is getting worse (Government of Ghana *et al*., 2011). This could partly be attributed to maladaptation which is, "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neill, 2010:211).

One of the causes of maladaptation is the collapse of institutionalised relationships which weakens the capacity to change behaviour positively or mobilise necessary resources for adaptation (Stringer *et al*., 2012). Corruption has also contributed to maladaptation through diversion of funds meant for development projects or interventions leading to shoddy works or causing projects to stall (Ghana Integrity Initiative, 2011). Another reason for maladaptation is that the institutions pursue their developmental agenda independently. As a result, there could be duplication or over-concentration of projects in some areas while other areas get little or none at all. A study by Stringer *et al*. (2012) in Malawi and Zambia found a similar lack of coordination of projects as an important constraint on sustainable development. Closely related to this is the failure of some projects resulting from insufficient linkages of the projects to local/indigenous practices (Kendie and Guri, 2007).

3.4 Synthesis

From the discourse above, it is very clear that there are a lot of interactions between humans and the environment which could lead to increased exposure and sensitivity and enhance or reduce the adaptive capacity of the human-environment system to cope with the challenge of climate variability and change. Although these activities play out at all spatial levels, there are subtle differences at the local level that have more bearing on the local people. These could be masked if the assessment is done at only higher levels. The methodological review section revealed that at every spatial level, there are different methods or tools available to conduct an assessment. The review of the study area supports the use of methods for data collection at the local level to fully characterise and analyse vulnerabilities to the hazards. However, in a data scarce environment like this, the utilisation of local level methods only will be expensive and time consuming. This research therefore adopted a hybrid approach, concentrating on more local phenomena with the higher level phenomena serving as a framework for projections. As such, methods appropriate to collect and analyse data at the local level were used as described in subsequent sections.

3.5 Data collection

3.5.1 Primary data

The data needed to answer most of the questions of objectives2 and 3 required the use of both quantitative and qualitative techniques in the field to collect the data. The quantitative data was collected using two sets of questionnaires[1] to obtain answers from different groups: one set of questionnaires for the residents of the selected communities (Fig. 3.2) and the

[1] See Appendices A1 and A2 for questionnaires (used to interview individual persons and institutions)

other for the institutions whose activities in one way or the other are related to these climate hazards. The questionnaire survey collected information about the socioeconomic activities and the perceptions and knowledge of the local people on climatic hazards and the impacts on their lives, as well as coping strategies and adaptive capacities.

A multi-stage sampling approach was used to select the individuals to participate in the questionnaire survey (Yansaneh, 2005). This approach was adopted in order to reduce costs and also account for any variation due to space or differences in characteristics within the population and ensure that a more representative sample is chosen (Yansaneh, 2005; United States Environmental Protection Agency, 2002). The first stage involved stratifying the Region into rural and urban districts. In doing this, districts with more than 50% of the population living in rural areas were classified as rural districts while those with a population of less than 50% percent in rural areas were classified as urban. This was achieved using the 2010 population and housing census classification by Ghana Statistical Service (2012) and resulted in 10 rural districts and 3 urban districts (Fig. 3.2). The second stage involved the selection of towns/villages in the 13 districts for the questionnaire administration.

Selection was made using a procedure similar to restricted random sampling (Elzinga *et al.*, 1998) in which the names of towns/villages within each district in the GIS database of Ghana were listed and selected at random by the lottery technique.

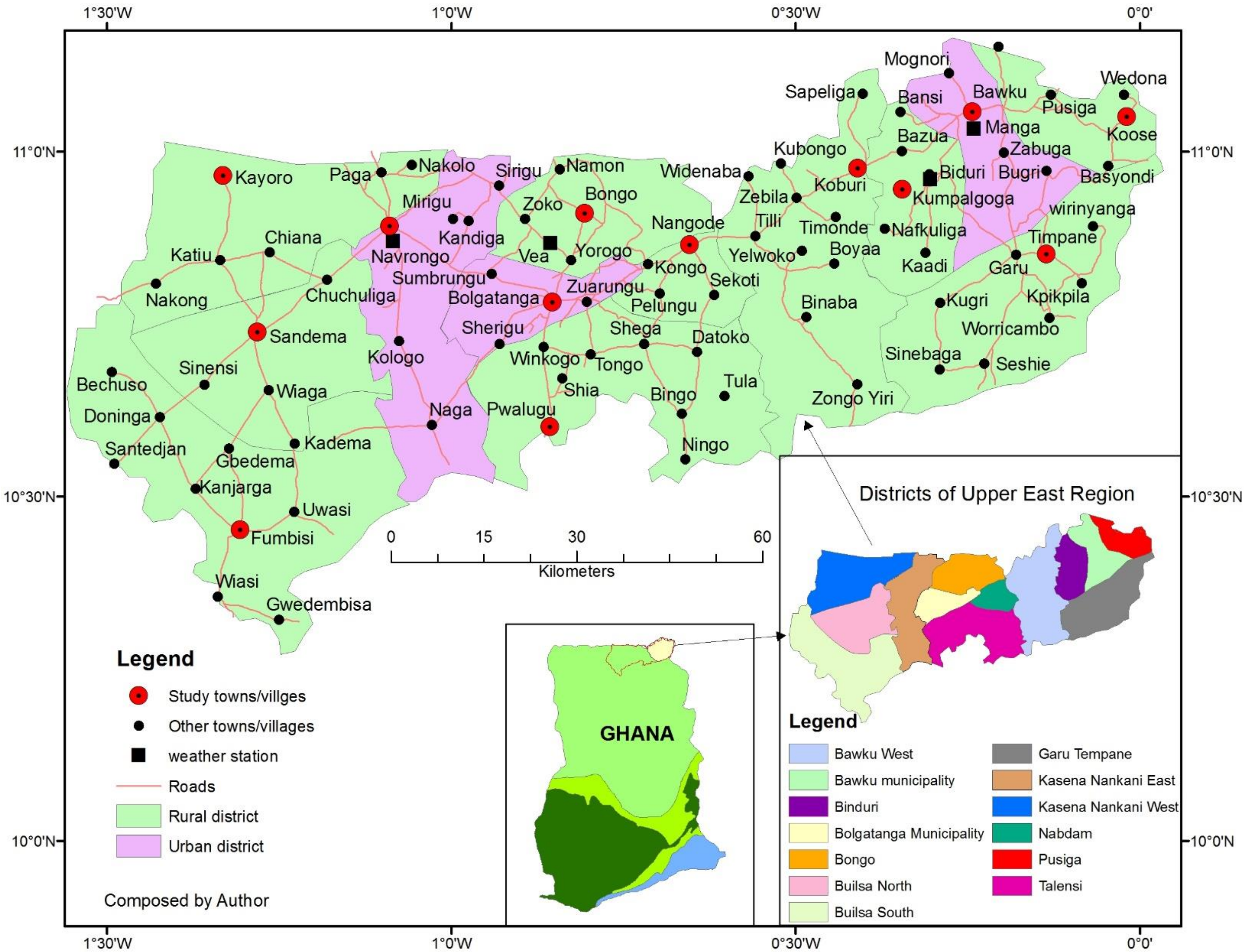

Fig. 3.2 Map showing selected Towns/Villages for questionnaire interviews

A small variation to the restricted random sampling technique is the purposive selection of the three big towns, in order to study urban characteristics. These were used as anchors and the towns/villages selected from the other districts was done with the condition that the distance between any two study communities should be more than 10 km.

This ensured good spatial distribution of sampling locations (Fig. 3.2). This sampling procedure was preferred chiefly because of its greater efficiency, particularly over simple random and systematic sampling, and also due to its ease of implementation in a GIS. Similar sampling procedures have been developed and/or used by many researchers (e.g. Stevens and Olsen, 2004; Elzinga *et al.*, 1998). It must further be mentioned that the initial village selected for the study in Binduri district was Kaadi but the vehicle developed a mechanical fault along the way and the nearest village, Kumpalgoga was surveyed instead. However, this village is more than 10 km from the nearest surveyed village and therefore falls within the selection criteria.

In determining the sample size (N), the formula $N = \frac{z^2 * \beta * (1-\beta)}{d^2}$, where z is the critical value at the chosen level of significance[2], β is the statistical power of the study and *d* is the margin of random error (also called confidence interval or size effect), was used (Fox *et al.*, 2007). The conventional values for the level of significance at α=5% (i.e. 1.96) and a power of 80% at a margin of error of ±5% (Fox *et al.*, 2007) were used, and a sample size of 246 was obtained. Due to resource constraints, an initial sample of 200 was decided for the household

[2] Level of significance accounts for the type I error while the statistical power accounts for the type II error, i.e., the level and power at which we are prepared to accept these errors. Refer to Fox *et al.*, 2007 for more detail.

survey with the remaining 46 to be distributed among institutions. However, dividing the 200 questionnaires among the two categories of rural and urban yielded 158 for the rural and 42 for the urban districts. It was not possible to use population census data to distribute the sample to the districts due to re-demarcation of some of the districts. Therefore, a round figure of 15 was given to each of the 10 rural districts, while that for the urban districts was increased to 60, making a total of 210.

The effect of over sampling and/or under sampling was assumed to be small and will not affect the outcome. As such, no weighting was applied as there is no way of determining the weights to be applied. Table 3.2 shows the distribution of the questionnaires among the districts.

Table 3.1 Distribution of questionnaires

District	Classification of district	Town/village selected	Number of questionnaires
Bawku Municipal	Urban	Bawku	20
Bawku West	Rural	Kubore	15
Binduri	Rural	Kumpalgoga	15
Bolgatanga Municipal	Urban	Bolgatanga	25
Bongo	Rural	Bongo	15
Builsa North	Rural	Sandema	15
Builsa South	Rural	Fumbisi	15
Garu-Tempane	Rural	Tempane	15
Kasena-Nankana East	Urban	Navrongo	15
Kasena-Nankana West	Rural	Kayoro	15
Nabdam	Rural	Nagodi	15
Pusiga	Rural	Koose	15
Talensi	Rural	Pwalugu	15
Total			**210**

Source: Based on field studies by Author

The assignment of the numbers for urban districts was arbitrary but was done using the importance/function of the town in the Region as well as its relative size. Thus, Bolgatanga was given a higher number because it is the Regional capital and also acted as the first point of call for people who fled from the Bawku conflict. Similarly Bawku was given a higher value than Navrongo because it is a bigger town. The towns/villages are organised in sections or clans and therefore a minimum of two questionnaires were administered in each section depending on the size of the town/village. Households were selected randomly in each section of the town/village, thus, ensuring good spatial distribution and further randomisation (Stevens and Olsen, 2004). In almost all communities, a community leader or the chief was contacted before the start of data collection in order to obtain consent and permission to carry out the work. The institutional questionnaires were distributed to the heads of district NADMO offices and Agricultural Development Units (DADU) as well as NGOs whose operations were related to hazards or adaptation to climate change. The NGOs were identified through discussions with the Regional Coordinator of NADMO and Agricultural Extension Agents. The NGOs contacted include Ghana Red Cross, World Vision (in Bawku West and Talensi-Nabdam Districts), ACDEP and Presby Farms (in Garu-Tempane and Builsa North Districts), sampled from the list of NGOs. In all, 24 institutions were contacted to be part of the study. All requested to study the questionnaire and respond accordingly since they may have to refer to some documents to provide answers to some questions. Thus the questionnaires were handed to them and collected a week later. Two officers failed to complete the questionnaire.

The qualitative techniques involved focus group discussions and taking photographic evidence which arguably has become a powerful tool of qualitative data collection (Snyder, 2012; Razvi, 2006; Pink, 2004). The focus group discussions centred on the perceptions of the local people on climate related hazards and their coping strategies, cultural practices and beliefs, community assets, and social networks. In all, five focus group discussions were held with details shown in Table 3.1. The discussants were selected following discussions with opinion leaders to reflect the diversity of the communities. These discussions were done in one urban and four rural communities.

Table 3.2 Number of participants and location of focus group discussions

Location	Classification	Number of participants			Drawn from	Participation in questionnaire	Date
		F	M	T			
Tempane	Rural	3	8	11	Farmer group	None	20/07/13
Koose	Rural	none	13	13	Farmer group	Some	25/08/13
Kumpalgoga	Rural	4	6	10	Community	Some	29/08/13
Bongo	Rural	5	7	11	Community	None	10/08/13
Navrongo	Urban	none	15	15	Community	None	16/07/13

Source: Based on field studies by Author (F = female; M = male and T = Total)

The discussants were drawn from opinion leaders, project beneficiaries, farmers and women associations to tap their experience and knowledge on the issues discussed. The atmosphere in each focus group discussion was friendly and all participants, including women contributed freely to the discussions, even though they were mixed with men. The discussions were recorded into field note books mostly by the researcher and a trained assistant. Immediately after the discussions, the notes were compared and reconciled before leaving the venue. Due to language barrier, the Navrongo focus group discussion was given to an experienced researcher who organised, facilitated and recorded the proceedings, and transcribed the recordings. In his case, a tape recorder was used. It must be mentioned that the initial intention was to carry out focus group discussions in all villages but after five discussions had been completed, it was realised that the information obtained was almost the same and therefore the data was assumed to have reached saturation point (Rebar *et al*, 2011).

3.5.2 Secondary data

The secondary data collected to aid in answering the questions raised in objective 1 included daily observed/recorded weather data from Ghana Meteorological Agency (GMet) from 1983 – 2012. This period was chosen primarily because it is the period within which about 8 agro-meteorological stations were operational and for which there are consistent data records. The time frame is also long enough to study climate change. More agro-meteorological stations were considered in order to investigate spatial variation in rainfall even at the local scale and how that influences vulnerabilities to hazards in the study area. Currently there are seven weather stations within the study area, but four stations (Fig. 3.2), namely, Navrongo[3], Vea, Binduri and Manga; had more consistent records of data within the period under consideration and so were chosen for the study. The observed weather data comprised daily rainfall, wind speed and minimum and maximum temperatures.

For objective 2 and part of objective 1, the data collected included crop yield data from the Statistics, Research and Information Division of MOFA and socio-economic data from the Ghana Statistical Service. The data on crops included crop production (tons) and area cultivated (in hectares) for the cereal, legume and root crops at district level. Annual health reports and other reports were downloaded from the Regional Health Directorate's website to extract information, particularly on health indices. Objective 3 relied on processed data from objectives 1 and 2 as well as data from the GIS database of Ghana, Landsat classification data from CERSGIS, and other relevant data (considered necessary for indicator development) as described in detail in the appropriate sections in chapter 6.

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[3] Navrongo station is the only synoptic station, the rest are agro-climatic stations.

3.5.3 Data analysis

Data analysis varied among the objectives and several combinations of analysis were done for each objective. To answer the questions raised in objective 1 which sought to investigate the exposure and sensitivity of the people and their livelihood activities to hazards, the GMet data was analysed using Standardised Precipitation Index (SPI). This characterised the hazards into their frequency, magnitude and duration. The analysis[4] of aspects of the primary data was used to confirm the characteristics of the hazards and to identify the threatened elements and the conditions considered unsafe.

Generally, the questionnaires were analysed using SPSS and the focus group discussions were subjected to manual content analysis. Photographs were taken to provide physical evidence. The crop data was analysed in Excel by calculating the crop sensitivity index to determine the sensitivity of crops to the hazards. The sensitivities of the other livelihood activities were analysed from the questionnaires and focus group discussions as well as the socio-economic data. The sensitivities and exposures were brought together to analyse the impacts (susceptibility) of the hazards. The adaptive capacities were analysed also from the field work and socio-economic data. The indicators for the components of vulnerability (exposure, sensitivity and adaptive capacity) were developed and mapped. The outputs of the analysis were largely tables, graphs and maps constructed with Excel, R and ArcGIS 9.3 and are presented in the subsequent chapters.

[4]Detail description of the analysis are presented in relevant sections of the proceeding chapters

Chapter 4 Determination of Hazards and Vulnerabilities

4.1 Introduction

It is well known that climate change whether human-induced or natural or both may produce hazards that are disastrous to human survival (Diodato, 2004). As stated in objective 1, the first step of vulnerability mapping will be to determine the kind of hazards that are prevalent and then see how systems react to these hazards, that is, identify their exposure and sensitivity. The reaction of the system could increase or decrease its vulnerability to the hazard(s). Thus, this chapter will focus on the shaded (gray) portion of the research framework (Fig. 4.1) to identify the hazards that occur in the area and to examine the sensitivity and susceptibility of the Region to these hazards.

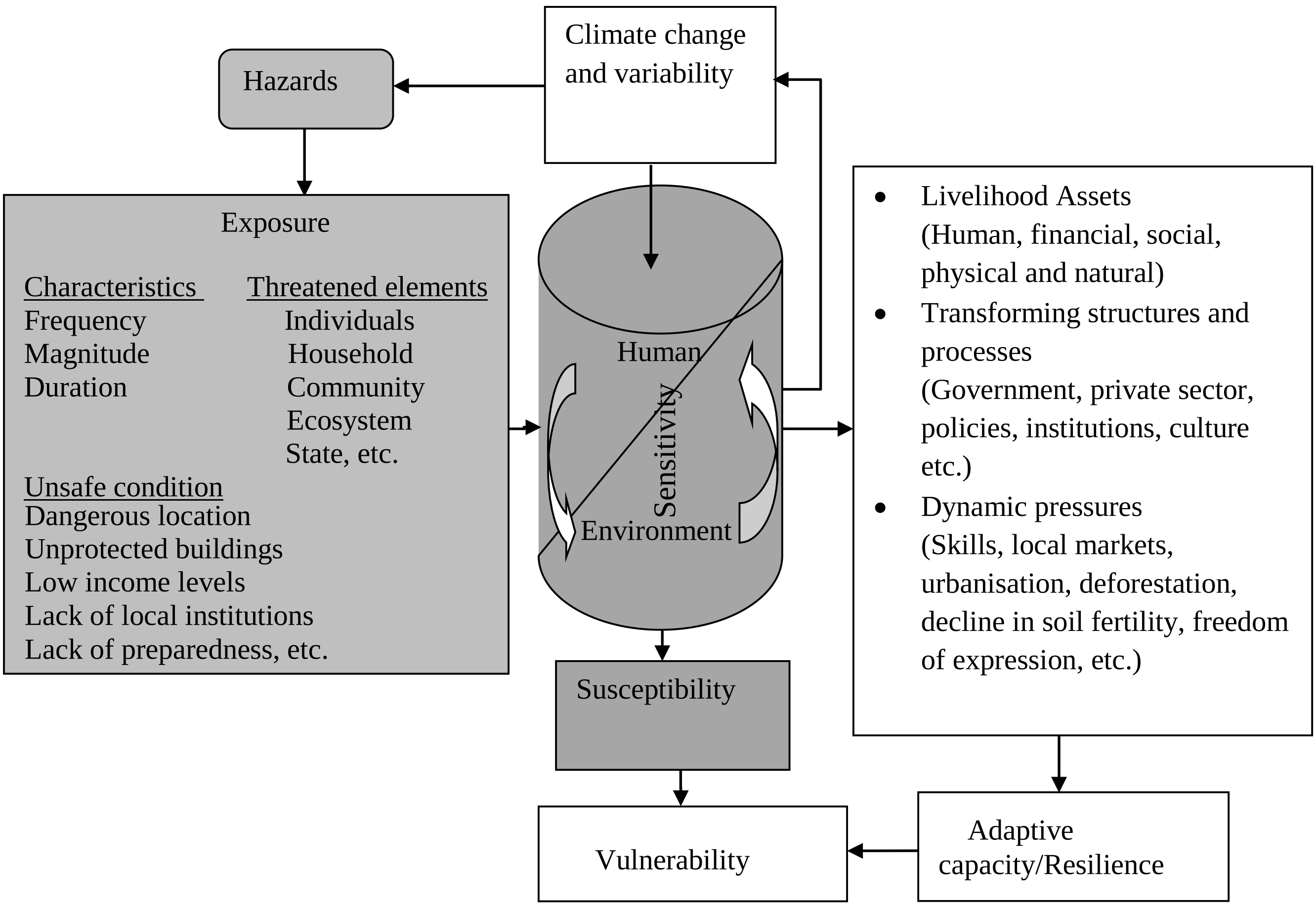


Fig. 4.1 Framework developed to analyse data for hazards and susceptibilities
Author's own construct

4.2 Hazards

The hazards that occur in the Upper East Region of Ghana are largely hydro-meteorological and therefore their presence and impacts can be analysed from the observed climate data supplemented with community knowledge or experiences of the hazards which are either recorded in documents or in the minds of residents. Thus data collected from GMet, NADMO as well as other published documents, were used alongside the questionnaire survey to analyse these hazards and their impacts.

4.2.1 Observed climate data

Rainfall is the major regulator of the climate of the Region (Owusu and Waylen, 2009) and is associated with hazards such as droughts, floods and sometimes come with strong winds. Thus, it is necessary to start the analysis by looking at the rainfall regime over the study period. Monthly total rainfall for the period 1983-2012 was plotted (Fig. 4. 2) to analyse the rainfall pattern and examine the changes that have taken place. Before plotting, months with total monthly rainfall below 20mm were removed. This was done because, according to FAO (2013), a total monthly rainfall of 20mm has an effective rainfall (i.e. rainfall available for plant use) of 2mm. Although this is far below the daily water requirements of 5 mm for most of the crops grown in the tropics (FAO, 2013), it can serve as a good benchmark.

The usefulness of Fig. 4.2 is in helping to analyse the start, cessation, duration and amount of effective rainfall in the rainy season. These variables are important in identifying drought (defined in section 4.2.1.1) and floods in the area. As can be seen in Fig. 4.2, there were very few years with rain in March (black bars) before 2000, but these almost disappear after 2000. April was more regular with rains throughout the 30 years.

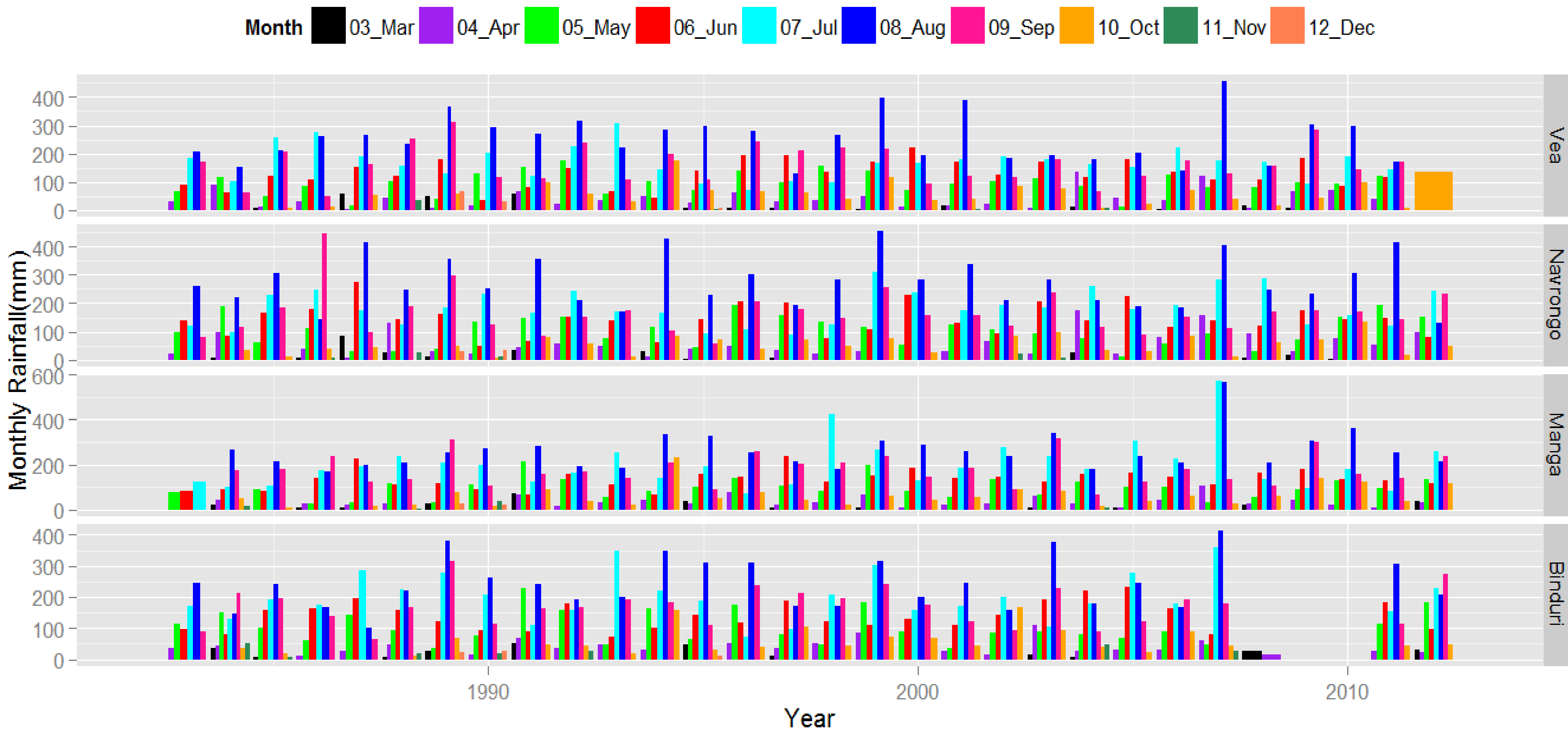


Fig. 4.2 Monthly Rainfall at four Agro-climatic Stations[5]
(Source: constructed with observed data from GMet)

[5] There were missing records for all months except October at Vea in 2012, from October to December, 1986 and from May 2008 to March 2011 at Binduri.

However, the interviews with residents showed differently. The majority (56%) think the onset of the rainy season is in June (Table 4.1) although throughout the period, May had a considerable quantity of rain, as indicated in Fig. 4.2. Each time the question of onset of rain was raised in a focus group discussion, it generated a lot of debate, with some supporting April or May while others supported assertions that the onset is in June.

Table 4.1 Month the rainy season starts

Start of rainy season			**End of rainy season**		
Month	**Before 2003**	**Last 5yrs**	**Month**	**Before 2003**	**Last 5yrs**
Mar	65 (32)	3 (1)	Aug	24 (12)	1 (1)
Apr	121 (59)	10 (5)	Sep	10 (5)	72 (35)
May	16 (8)	76 (37)	Oct	25 (12)	114 (55)
Jun	3 (2)	116 (56)	Nov	135 (65)	19 (9)
Jul		2 (1)	Dec	13 (6)	
Total	205	207	Total	207	206

Source (Based on field studies by Author) N.B: Values in brackets are percentages

Careful study of Fig. 4.2 reveals that rainfall in May before 2000 was generally higher than it was after 2000 for all stations. This may likely support the argument that the onset is around the last week of May to early June. It was mentioned during the focus group discussions that after rainfall in April, one can feel the heat in his/her body system and sometimes vapour can be seen rising from the soil. The soil, according to focus group discussions, at the time of April, is literally baked by the high temperatures and needs further rains to become conducive for planting. Most often, the April rain is followed with dry spells coupled with high temperatures, and therefore any planting in April sees the crops die and they will have to replant. These feelings of farmers support the assertion of Mugalavae *et al*. (2008, cited in Simelton *et al*., 2012) that farmers use practical agronomic ways to determine the onset and cessation of rain. However, the farmers' responses on cessation (Table 4.1) correspond with the observed meteorological data. There was agreement by all participants in all discussions with regards to cessation in October and some indicated that in the last decade, November rains are usually followed by the harmattan dust, though it hardly rained in November recently.

The forward shift of the rainy season from somewhere around April to May/June and the cessation back from November to October in the last decade (particularly after 2000) implies a shortening of the season. Fig. 4.2 also shows variation in the amount of rain that falls in each month, rising to its peak in July/August of most years in all stations. With the exception of 2007, there is a general increase in rainfall from east[6] to west, in accordance with the two savannah zones (i.e. the Sudan in the east and the Guinea in the west). These findings are keeping with the observations made by the respondents in the questionnaire survey (Table 4.2). The majority (40%) of the respondents also see the length of the rainy season becoming shorter than it was before 30years ago. The cross-tabulated results in Table 4.2 included a chi-square test with a p-value of 0.001, signifying that the responses differed significantly among the villages. The explanations offered in the focus group discussions as to how they are able to make these observations were that the time of planting is now very late. One participant in the focus group discussions at Koose said "we used to plant in the third month after Christmas (i.e. March) but now we are planting in the sixth month (i.e. June) and the rain doesn't go far. Most often after 4 months, it stops". They also used the planting of short duration varieties, particularly maize, instead of their traditional crops as a means of justifying the changes. In the questionnaire survey, more respondents (14%) reported a decrease in quantity of rainfall than an increase (2%) in Table 4.2. The rest said it is irregular or does not rain at the right time.

[6] The order of the stations east-west is Manga, Binduri, Vea and Navrongo

Table 4.2 Observed changes in rainfall pattern over the last 30 years

	No. of respondents who observed changes						**Total**
Name of town/ village	**Shortening of length of rainy season**	**Decrease in rainfall**	**Increase in rainfall**	**Increase in dry spell**	**Irregular[7]**	**Does not rain at the right time**	
Bawku	4 (25)	3 (19)	1 (6)	1 (6.2)	7 (44)	0	16
Bolgatanga	13 (52)	5 (20)	0	5 (20)	2 (8)	0	25
Bongo	2 (13)	3 (20)	1 (6.7)	0	9 (60)	0	15
Fumbisi	7 (47)	2 (13)	0	1 (6.7)	3 (20)	2 (13)	15
Kayoro	6 (40)	1 (7)	0	0	8 (53)	0	15
Koose	6 (40)	1 (7)	0	3 (20)	5 (33)	0	15
Kubore	10 (67)	0	0	2 (13)	2 (13)	1 (7)	15
Kumpalgoga	1 (7)	6 (40)	0	2 (13)	6 (40)	0	15
Nangodi	4 (27)	0	0	1 (7)	10 (67)	0	15
Navrongo	3 (20)	7 (47)	0	1 (7)	4 (28)	0	15
Pwalugu	10 (67)	0	0	0	5 (33)	0	15
Sandema	9 (60)	0	1 (7)	0	5 (33)	0	15
Tempane	8 (53)	0	1 (7)	2 (13)	4 (27)	0	15
Total	83 (40)	28 (14)	4 (2)	18 (9)	70 (34)	3 (2)	206

Source (Based on field studies by Author) N.B: numbers in brackets are row percentages

The same feelings were gathered from the focus group discussions as each person attested to the decrease of rainfall. From the observed data, August is the wettest month in the Region and it is more often than not, preceded with heavy rains in July (see Fig. 4.2). It can be seen from Fig. 4.2 that the year 2007 recorded the highest amount of rainfall in July/August over the 30 year period and was the year on record with the most disastrous flood in the area (NADMO, 2011). Coincidentally, due to the high relative humidity (80%) and other atmospheric variables such as cloud cover present around July/August, maximum daily temperatures are relatively low averaging around 32°C (Fig. 4.3) and thus lowering evapotranspiration.

[7] All multiple choices were grouped as irregular

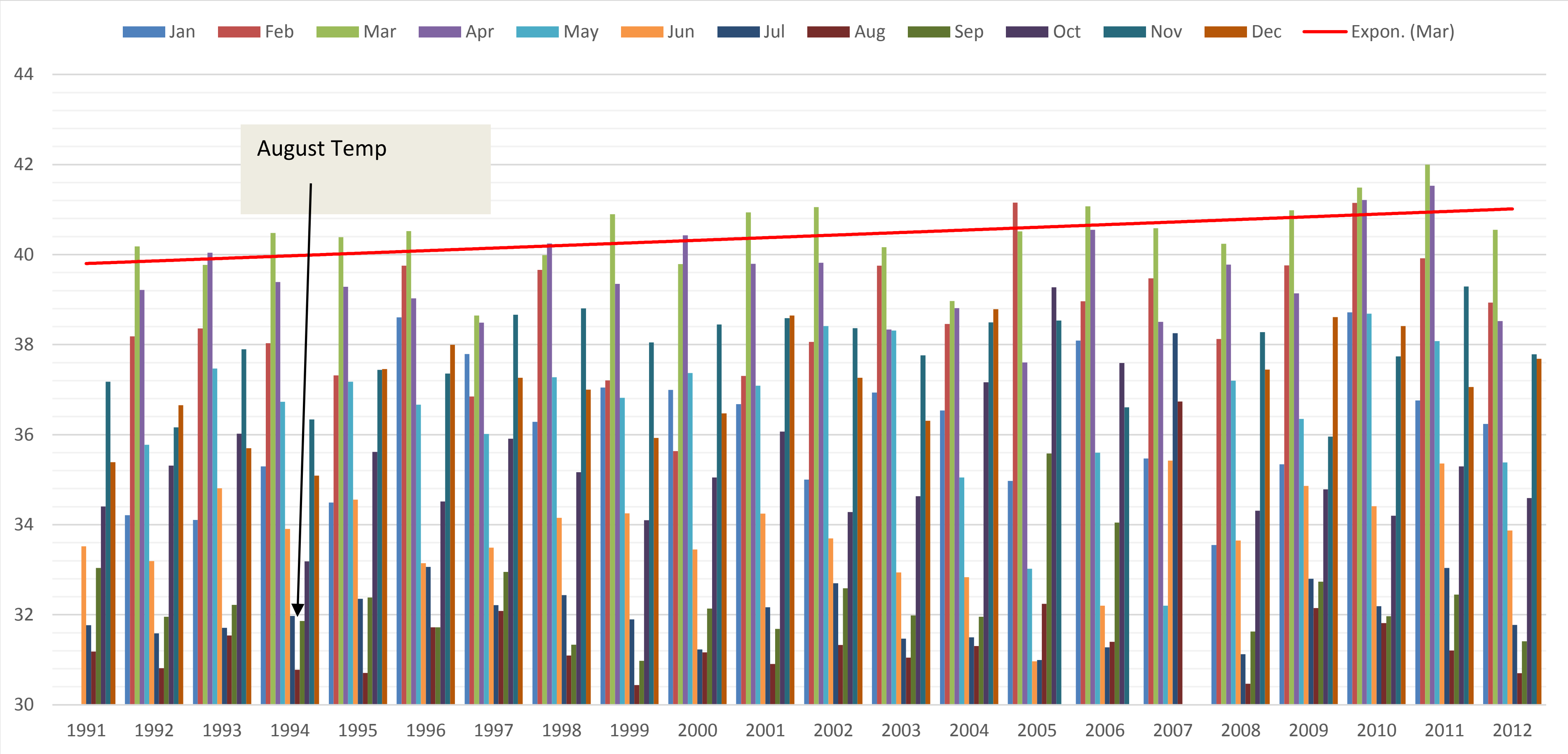


Fig. 4.3 Maximum average monthly temperatures (°C)[8] from 1991 to 2012

Source: Created with data from GMet

[8] All low temperature values correspond to July – September period.

The rain falls regularly and heavily within the July – September period and this saturates the soil as evapotranspiration is low during that period. Thus, any additional rain results in flooding. The floods are exacerbated by the release of the dam waters from Burkina Faso during that period when the major rivers are almost full to capacity. Generally, March has been the hottest month. It is therefore clear that the variability in the rainfall in terms of its onset, regularity, duration and cessation could produce hazards and this demands a detailed study of the data to identify the hazards prevalent in the Region.

4.2.2 Exposure of the human-environment system to hazards

Hazards are events that may cause loss of life or harm to human beings or damage to and/or loss of livelihoods when exposed. Therefore diagnosis of hazards in this study was carried out by analysing exposure. As indicated in Fig. 4.1, exposure is determined by looking at the characteristics, the dangers of the hazard to the exposed elements and conditions which make these elements unsafe. This then paved way to analyse the sensitivity of the exposed elements to the hazards and thus examine the potential impacts (susceptibility) of the hazards.

4.2.2.1 Characteristics

The characteristics of exposure to a given hazard are defined by the frequency, magnitude and duration of the hazard. The household survey sought to find out from experiences of the people who live in the area and then compare that with observed meteorological data. The responses identified some hazards and indicate that there are variations in the occurrence of these hazards across the Region. A cross tabulation of communities where the questionnaire survey was carried out against the various hazards identified, show that floods, droughts, windstorms, high temperatures and heavy precipitation do occur in the Region, but that they vary from place to place and even within the communities depending on function and proximity to or type of drainage system (Table 4.3).

Table 4.3 The occurrence of hazards from questionnaire survey[9]

	Number of respondents					
Town/village	**droughts**	**High temperature**	**Floods**	**High rainfall**	**Windstorms**	**Sample size**
Bawku	18	18	2	15	18	**18**
Bolgatanga	25	11	21	3	23	**25**
Bongo	15	15	3	12	15	**15**
Fumbisi	15	14	15	1	14	**15**
Tempane	15	15	15	15	15	**15**
Kumpalgoga	15	15	15	15	15	**15**
Koose	15	0	15	15	15	**15**
Kubore	15	1	15	1	14	**15**
Nagodi	15	15	13	1	15	**15**
Navrongo	15	10	8	13	15	**15**
Pwalugu	15	15	15	0	15	**15**
Kayoro	15	15	0	12	15	**15**
Sandema	15	15	15	4	15	**15**
Total	**208**	**159**	**152**	**107**	**204**	**208**

Source (Based on field studies by Author)

As shown in Table 4.3, all 208 respondents attested that droughts occur in the area. The next hazard reported by a high number of respondents to be occurring in the area was windstorm while high precipitation (rainfall) had the lowest number of respondents reporting its occurrence. With the exception of droughts which had all respondents agreeing to its occurrence, responses varied from village to village (see Table 4.3) with regard to the other hazards. Thus, depending on where you are located within the community, you experience the effects of different hazards. In relation to the frequency of occurrence/severity of these

[9] This was a multiple choice question and interviewees were allowed to provide more than one answer.

hazards, temperature was generally observed by the respondents to be increasing especially in March. This corroborated well with the observed data as indicated with the trend line in Fig. 4.3. Besides high temperature, drought was also the most widely acknowledged hazard that occurs frequently in the Region with about 79% of respondents reporting that it occurs every year (Table 4.4).

Table 4.4 Frequency of droughts in the Region from 1983 – 2013

	No. of respondents				
Town/village	**every year**	**once every 2years**	**once in every 5years**	**irregular**	**Total**
Bawku	16 (88%)	1 (6%)	1 (6%)	0	18
Bolgatanga	21 (84%)	4(16%)	0	0	25
Bongo	14 (93%)	1 (7%)	0	0	15
Fumbisi	14 (93%)	1 (7%)	0	0	15
Tempane	9 (60%)	5 (33%)	0	1 (7%)	15
Koose	7 (47%)	7 (47%)	1 (6%)	0	15
Kubore	14 (93%)	1 (7%)	0	0	15
Kumpalgoga	8 (53%)	5 (33%)	2 (14%)	0	15
Nangodi	14 (93%)	0	0	1 (7%)	15
Navrongo	13 (86%)	1 (7)	1(7%)	0	15
Pwalugu	8 (53%)	0	0	7(47%)	15
Kayoro	12 (80%)	0	0	3 (20%)	15
Sandema	14 (93%)	1(7%)	0	0	15
Total	164 (79%)	27 (13%)	5 (2%)	12 (6%)	208

Source: Based on field studies by Author

Drought and dry spells were difficult to distinguish in the local languages and were seen as the same phenomenon by the respondents. Therefore, the duration varied largely from 2 weeks to 4 weeks (Table 4.5). It must however, be mentioned, that the questionnaire survey took place during and after a long dry spell/drought that started in May and ended in mid-July, yet it did not visibly influence the answers provided. This could be explained by the variation in duration of the dry spells across the Region and also the lack of recording dates; therefore durations are estimated from memory. Only the educated provided a closer estimation of duration of one month or more. Another observation made was that farmers measure the onset of a dry spell from the time their crops begin to wilt and not from the last rained day, and so perceive drought/dry spells differently, as found by Simelton *et al*. (2013).

Table 4.5 Duration of drought

	Length of dry spells							
Town/village	**two weeks**	**three weeks**	**one month**	**more than 1month**	**cannot tell**	**2 & 3 weeks**	**1 week or less**	**Total**
Bawku	5 (33%)	4 (27%)	5 (33%)	1 (7%)	0	0	0	15
Bolgatanga	4 (17%)	6 (25%)	13 (54%)	0	1 (4%)	0	0	24
Bongo	2 (13%)	6 (40%)	6 (40%)	0	0	1 (7%)	0	15
Fumbisi	2 (13%)	8 (54%)	5 (33%)	0	0	0	0	15
Tempane	7 (47%)	2 (13%)	4 (27%)	2 (13%)	0	0	0	15
Koose	3 (20%)	2 (13%)	10 (67%)	0	0	0	0	15
Kubore	8 (53%)	4 (27%)	1 (7%)	0	0	0	2 (13%)	15
Kumpalgoga	9 (64%)	4 (29%)	0	0	1 (7%)	0	0	14
Nangodi	0	0	0	15 (100%)	0	0	0	15
Navrongo	5 (33%)	7 (47%)	3 (20%)	0	0	0	0	15
Pwalugu	0	0	2 (13%)	13 (87%)	0	0	0	15
Kayoro	2 (14%)	10 (72%)	2 (14%)	0	0	0	0	14
Sandema	2 (13%)	11 (74)	2 (13%)	0	0	0	0	15
Total	49 (24%)	64 (32%)	53 (26%)	31 (15%)	2 (1%)	1 (1%)	2 (1%)	202 100%)

Source: Based on field studies by Author

However, in order to cross validate the hazards identified by the respondents, a Standardised Precipitation Index (SPI) was calculated using the precipitation values. The SPI was chosen over other drought indices because it is flexible, simple, suitable for shorter timescales, spatially consistent and its probabilistic nature gives it a historical context and thus, it is suitable for early warning as well as decision making (World Meteorological Organisation, 2012). It also offered the opportunity to estimate the magnitude of an event by summing up the values in a continuous (positive or negative) direction. The SPI was calculated for 1-

month, 3-month, 6-month, 9-month and 12-month timescales (see Appendix B for the SPIs). The 1- and 3-month time scales were useful in analysing dry spells and the 3- and 6-month timescales were used to analyse agricultural drought whereas the 6- to 12- months timescales were used to analyse hydrological droughts, useful for flood and water resource monitoring (World Meteorological Organisation, 2012).

In the observed rainfall records, Manga had some missing data for some months in 1983 and 1986; Binduri had similar missing data in 1983, 1986 and from May 2008 to December 2010; whereas Vea had only one record (October) in 2012. These missing values affected the calculation of the SPI values in those missing months as well as the succeeding few months, and returned no meaningful information for those. Therefore years with complete information were used to do the analysis. Thus the SPI values were taken from 1988 to 2012 which had continuous data but without 2012 values for Vea and 2008 for Binduri. This yielded a 25 year period of quality SPI values and offered the opportunity to compare the years before 2000 to the years 2000 and after, as 2000 acted as a median year, to ascertain the trend between the two decades.

The SPI values show dry and wet conditions and are useful to analyse drought and floods. The results indicate that throughout the period (1988 to 2012) and across all the stations, no year passed without the occurrence of dry spells. These dry spells occurred within a month or within every month of the whole rainy season. In cases where these dry spells were severe, they resulted in droughts. According to McKee *et al*. (1993), a drought event occurs when the SPI for a particular timescale is continuously negative and reaches a value of -1 or less (cited in World Meteorological Organisation, 2012). The drought event begins when the SPI value for a particular timescale first falls below zero and ends when it crosses back to positive after it had reached -1 or less. The magnitude was calculated by summing up the negative values within the drought period (McKee *et al.*, 1993, cited in World Meteorological Organisation, 2012). Using these definitions, the frequency, duration, onset, cessation and magnitude of drought for all the stations were extracted as shown in Table 4.6. Although the Table is constructed from the 3-month SPI, the values were compared with the 6-month SPI and they both indicated drought periods in nearly all the cases. The differences between the 3- and 6-month SPI were largely on the onset and cessation which occurred in some few cases and there were also differences in the magnitudes of the SPIs.

Generally drought can be said to occur every other year in the Region but the frequency varies from location to location. From Table 4.6, the frequency of drought varied from 9 times at Binduri to 13 times at Vea in the 25 years of study. Similarly the duration varied from 1 month to 8 months meaning it covered the entire rainy season in those years it reached 8 months. Most of the drought cases, especially those that lasted 4 or more months, occurred at the critical period of the rainy season when crops grow up until harvesting. Though more of the drought periods occurred before 2000, those that occurred in 2000 and after generally had longer duration with bigger magnitudes. It is evident from the SPI that drought is a major problem in the Region. Furthermore, the responses of inhabitants shown in Table4.3 corroborate very well with the SPI findings. As indicated earlier, dry spells occur every year and could last two weeks or more and in some cases the months after dry spells receive low rainfall. Thus when these dry spells are combined with droughts, it will seem that droughts occur every year (as noted by about 79% of respondents in Table 4.4). Unlike drought which occurred everywhere in the Region, floods were seen only in urban areas, water logged areas or along rivers/streams.

Table 4.6 Characteristics of drought between 1988 and 2012 extracted from 3-month SPI

		Year												
Station	**characteristics**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Binduri	Duration (months)		3	8	4						4			8
	Magnitude		2.55	4.56	1.92						2.89			5.85
	Onset/End		A/J	Ma/O	Ju/O						Ju/O			Ma/O
Manga	Duration (months)	1	5	8			3	3						3
	Magnitude	1.58	4.07	5.09			1.84	2.78						2.23
	Onset/End	Au/O	A/Au	Ma/O			Au/O	J/Au						Ma/M
Navrongo	Duration (months)	4	4	2, 5			8	2	8			5		4
	Magnitude	3.64	2.96	4.97			5.65	3.08	7.93			3.84		5.02
	Onset/End	Ju/O	A/Ju	Ma/A, J/O			Ma/O	J/Ju	Ma/O			J/O		Ma/J
Vea	Duration (months)			2, 3		1	4	4	5		3			3, 2
	Magnitude			3.75		1.82	3.94	3.77	3.69		2.89			5.36
	Onset/End			Ma/A, J/Au		Ma/A	Ma/J	J/S	A/S		Au/O			Ma/M, S/O
		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
Binduri	Duration (months)	8	8		2				N/A					
	Magnitude	5.64	4.34		2.64									
	Onset/End	Ma/O	Ma/O		S/O									
Manga	Duration (months)	5			3				6			8		
	Magnitude	2.73			4.13				4.11			5.78		
	Onset/End	Ma/Ju			Au/O				M/O			Ma/O		
Navrongo	Duration (months)				2	8							3	
	Magnitude				1.18	6.5							2.11	
	Onset/End				S/O	Ma/O							Au/O	
Vea	Duration (months)		5	3	5	8			5			5		
	Magnitude		2.09	2.14	4.57	5.77			4.92			2.91		
	Onset/End		Ma/Ju	Ma/M	J/O	Ma/O			A/O			Ju/O		
Station		Binduri			Manga			Navrongo			Vea			
	Frequency	9			10			11			13			

(Source: Based on SPI values computed by Author) N.B: Ma=March, A=April, M=May, J=June, Ju=July, Au=August, S=September, O=October

These areas get flooded for a range of obvious reasons such as choked gutters or poor drainage systems in urban areas, more runoff in flood prone areas and rivers/streams overflowing their banks. Floods lasted between some few hours in a day and about a month depending on the type and location. From the questionnaire survey, the occurrence of floods also varied from location to location (Table 4.7).

Table 4.7 Frequency of floods according to respondents

Town/village	**every year**	**once every 2yrs**	**once in every 5yrs**	**once in every 10yrs**	**irregular or not frequent**	**can't tell**	**Total**
Bawku	0	0	0	0	0	0	0
Bolgatanga	13 (52%)	8 (32%)	1 (4%)	1 (4%)	0%	2 (8%)	25
Bongo	4 (67%)	0	1 (17%)	1 (7%)	0	0	6
Fumbisi	7 (47%)	4 (27%)	2 (13%)	0	2 (13%)	0	15
Tempane	7 (47%)	5 (33%)	2 (13%)	1 (7%)	0	0	15
Kubore	13 (87%)	2 (13%)	0	0	0	0	15
Kumpalgoga	12 (80%)	2 (13%)	1 (7%)	0	0	0	15
Koose	0	0	0	0	0	0	0
Nangodi	5 (39%)	0	0	0	8 (62%)	0	13
Navrongo	1 (13%)	2 (25%)	2 (25%)	0	3 (37%)	0	8
Pwalugu	15 (100%)	0	0	0	0	0	15
Kayoro	2 (15%)	0	4 (31%)	0	7 (54%)	0	13
Sandema	3 (20%)	10 (67%)	2 (13%)	0	0	0	15
Total	82 (53%)	33 (21%)	15 (10%)	3 (2%)	20 (13%)	2 (1%)	155 (100%)

Source: Based on field studies by Author

Almost all respondents living in communities along the White Volta (Kubore, Kumpalgoga and Pwalugu) said floods occur every year. None of the respondents in Bawku experienced floods and this could be explained by the fact that none of them live in or have anything to do with flood prone areas in the town (if there are any). Koose also reported no flooding because the entire village is in the uplands and nowhere near a river. Just as was done with drought, the SPI was used to examine the wetness condition of the Region and flooding.

This is because the SPI is normally distributed with mean of zero and standard deviation of one (McKee *et al*., 1993, cited in World Meteorological Organisation, 2012). Also Seiler *et al*. (2002) used the SPI to reconstruct flood events in Argentina and found them useful especially over longer timescales such as 12months and 24months. Thus, 12-month SPI was used in combination with 9-, 6- and 3-month SPIs to examine the hydrological conditions and floods in the Region. Here a wet condition occurs when the SPI is continuously positive and reaches +1 or higher and ends when it goes below zero (Seiler *et al*., 2002). Examination of the 12-month SPI (Appendix B) indicate wet conditions in 1989 extending into 1990 and ending in September 1990. Another wet condition occurred in 1992/1993 but this happened in Vea with the other stations remaining dry or normal. In 1995, except in Navrongo which was dry, all other stations had wet conditions. Wet conditions also occurred in 1999, 2000, 2004, 2007 and 2010 in all stations. The variation in wet spells is not as marked as those of dry spells in the Region. These wet conditions are often useful for the Region as they contribute to recharging the ground water system and ensuring enough surface water for dry season activities, domestic use and watering of animals (Obuobie, 2008).

However, the wet spells also have a destructive side through flooding. In the records, 1989, 1995, 1999, 2007 and 2010 were years of widespread flooding in the Region (UNDP, 2009; The World Bank Group, 2009; NADMO, 2011). These years correspond perfectly to those years with very wet conditions. It can be noticed that 2000 and 2004 had very wet conditions but never resulted in flooding. The explanation that could be deduced to that effect is that, these wet conditions occurred in the early part of the rainy season and waned towards the last 3 months. The early part of the rainy season is characterized by high daily maximum temperatures (around 40°C) and low relative humidity (37%) and therefore evapotranspiration is high. The soils at this time of the rainy season are not also saturated and absorb more of the rain water. Thus, relatively, there is less runoff at the early stages than in July-September when all the indicators above are reversed. In any year that July, August and September are dry, then flooding does not occur and this can be observed in the SPI. Indeed, as can be seen in 2000, it had very wet condition until July but became very dry in July to September. It passed as a drought year in the 3-month and 6-month SPIs in most of the stations. A similar situation happened in 2004.

4.2.2.2 Threatened elements

Having determined the characteristics of the hazards, it is necessary to examine the elements threatened by the hazards. This will lead to the examination of the conditions that make them threatened by these hazards. The elements identified from the survey to be threatened varied according to the hazard. Table 4.8 shows the properties and livelihood activities affected by each hazard.

Table 4.8 Consequences of hazards[10]

Hazard	Effects	
	Direct	**Indirect**
Floods	Human life, crop failure, buildings, personal belongings, animals, drinking water, roads, public properties	Health burden, food shortage,
Droughts	Crop failure, health burden, water scarcity, lack of pasture, hardening of soil, destruction of vegetation	Food shortage, wasting and death of livestock, bushfires
High temperatures (warming)	High body temperatures, water scarcity	Health burden
Windstorms	Destruction vegetation, roofs and crops, human life, loss of livestock	Homelessness, closure of schools
High precipitation	Collapsing of buildings	Health burden, live lost, loss of livestock, flooding

Source: Based on field studies by Author

[10] Health burden is the disease or sickness itself together with the cost of treating it.

It was difficult to detach the effects of temperature from droughts as most of the participants noted that except in the dry season, temperatures are moderated by rainfall. This is consistent with the findings of Owusu and Waylen (2009) that the weather in the savannah zone is moderated by rainfall.

4.2.2.3 Unsafe conditions

Human activities are increasingly located in hazard prone areas. This is most often attributed to population pressure on land to satisfy such activities (Gyasi *et al*., 2014). In addition to population increase, those who farm along the rivers used soil fertility and the piece of land being their only property as reasons for continuous human activities in flood prone areas. To these people, though the floods are sometimes destructive, they also benefit from them because floods deposit organic matter on their land making it fertile. In the urban areas, urbanisation and low cost of land in such areas were the drivers for people putting up buildings in flood prone areas. Observations reveal that the buildings in such areas are poorly laid out, with poor or no drainage systems and therefore water from the roofs is not channeled out properly. The poor road network also makes it difficult for emergency and relief agencies to move freely and carry out their work in times of need.

Besides, for an agrarian economy which depends largely on subsistence agriculture, the destruction of crops and grassland due to drought or flood affects incomes. From the survey, about 10% of the respondents were completely not involved in farming. Forty-one percent engaged solely in farming while the remainder were practicing farming together with other activities. It was found that the food produced from the farm is not able to meet the family food requirements and the respondents attributed the declining trend of household food production largely to changes in weather patterns (Table 4.9).

Table 4.9 Cause of reduction in source of household food supply (in percentages)[11]

	Number of respondents								
Town/ village	Weather pattern	Soil fertility	Land size	Rising cost of production	Pest invasion	Old age	Can't tell	No answer	Sample size
Bawku	8	0	0	2	0	0	0	9	18
Bolgatanga	4	11	3	5	0	0	1	3	25
Bongo	15	14	3	8	0	0	0	0	15
Fumbisi	9	11	0	5	2	0	0	3	15
Tempane	1	4	0	0	0	0	0	10	15
Kumpalgoga	6	1	0	4	0	0	0	7	15
Koose	4	7	0	2	0	0	0	5	15
Kubore	11	3	0	0	0	1	0	2	15
Nagodi	14	0	0	0	0	0	0	1	15
Navrongo	12	2	0	4	0	0	0	1	15
Pwalugu	15	0	0	0	0	0	0	0	15
Kayoro	14	1	0	11	0	0	0	0	15
Sandema	10	12	1	1	0	0	0	0	15
Total	**123**	**66**	**7**	**42**	**2**	**1**	**1**	**41**	**208**

Source: Based on field studies by Author

Some people did not provide an answer to this question and these are people who did not know whether there is a reduction in production or not because they do not measure, or people who do not see decrease in yield, were not involved in farming or for any similar reason, and hence the high figures in 'no answer' column. From the responses changes in weather patterns and soil fertility are the major causes of failure in agricultural production. However, in the focus group discussions, changes in weather patterns were considered more destructive than declining soil fertility and this is reflected in the questionnaire responses. This is consistent with the findings of the IPCC (2014b) and many other studies that climate change will have untold effects on crop production in Africa. Low agricultural productivity affects food prices in the market and sometimes, when the situation becomes dire, the

[11] Respondents provided more than one option

government calls for external aid. There was generally lack of preparedness particularly in relation to drought and food insecurity and the institutional heads or representatives attributed this to uncertainties associated with the prediction of the hazards. The preceding discussions have shown that the people in the Region and many of their livelihood activities are exposed to climatic hazards. An examination of the sensitivity of these activities is therefore necessary.

4.2.3 Sensitivity of the human-environment system to the hazards

As defined by the IPCC (2014b), sensitivity is a measure of the degree to which a system is affected, either adversely or beneficially, by climate variability or change. In the Upper East Region, the occurrence of these hazards has always posed one problem or another to the inhabitants. Advantages are delivered as well, though these are considered under the later analysis of adaptive capacity. Thus sensitivity was measured in terms of the adverse effects of the hazards on the ecosystem and its inhabitants. Effects on the ecosystem identified by the participants (in the field survey) include soil hardening and erosion, destruction of vegetal cover and water scarcity. It was difficult to quantify the sensitivity of these to climatic hazards as human activities are believed to contribute greatly (Mengisteab, 2010). However, the effects on humans and their activities were qualitatively ranked (Table 4.10).

Table 4.10 Sensitivity of human-ecological system to hazards[12]

Hazard	Severity	No. of responses
Floods	Very severe	14
Drought	Very severe	20
Temperature	Severe	17
High precipitation	Very severe	11
Windstorm	Severe	14
Bushfire	Severe	15

Source: Based on field studies by Author

Also statistics from NADMO on the effects on the 2007 and 2010 floods show the level of sensitivity of human life to the hazards (Table 4.11). The 2007 floods were severer than 2010 in terms of volume of flood water and impacts. It affected more houses and displaced more people as shown in Table 4.11.

Table 4.11 Statistics on the impact of floods in the Upper East Region

Year	No. of collapsed houses	No. of displaced People	No. of deaths
2007	19,244	109,367	34
2008	-	-	-
2009	-	-	-
2010	338	9,085	14

Source (NADMO, 2011)

From the questionnaire survey, more than 57% of the respondents indicated they have shifted from planting traditional crops such as sorghum, millet, groundnuts, local potatoes, etc. to improved and short duration varieties of maize with the major cause of this shift being increasing incidence of drought. The findings corroborated well with the area under cultivation for five major crops in the Region (Fig. 4.4). From Fig. 4.4, as the area of

[12] This table is a general picture across the Region, district level data show slight variations with regards to floods. The rankings were done by the respondents, institutional representatives and in the group discussions

cultivation for millet and sorghum are decreasing linearly, that of maize and rice are increasing; an indication that increasingly, more and more land is used for the cultivation of maize at the expense of other crops. If this trend continues, these crops may disappear from the cropping calendar. Maize and rice became the major crops produced in the Region in 2012 and from the questionnaire responses, maize was found to be the major crop produced by over 57% of the respondents with about 4% cultivating maize and another crop. Thus, in total, more than 61% of farmers in the Region are now cultivating maize as their major crop. Observations during the field work suggest that the area under cultivation for maize may double or even be higher by the end of the 2013 cropping season.

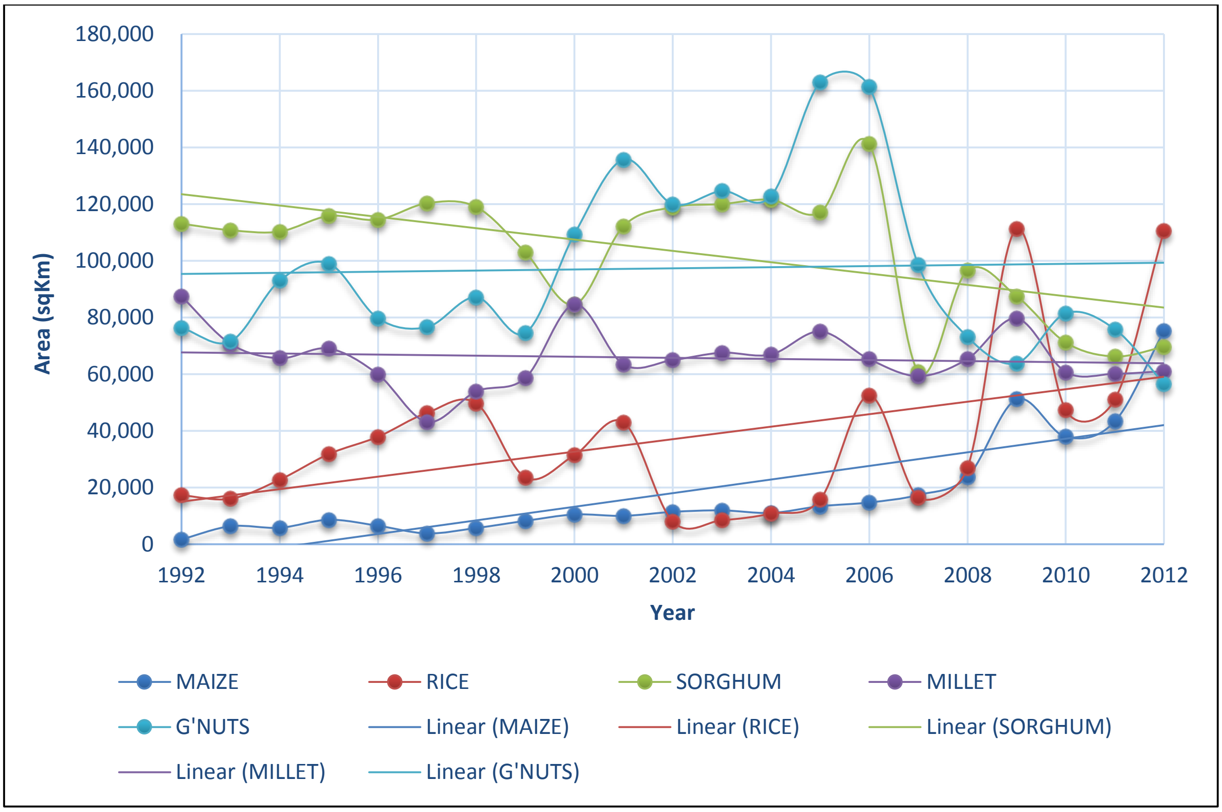


Fig. 4.4 Area of cultivation of major crops in hectare (1992-2012)[13]
Source: created with data from MOFA

[13] These are the only years with records from the SIRD of MOFA.

As can be seen in Fig. 4.5, large tracts of land, even around the compounds, are being used to cultivate maize. The maize varieties cultivated were said to be of short duration and able to withstand the dry spells and droughts better than the traditional crops. By implication, maize has become a major staple food crop which over 20 years ago, it was not.

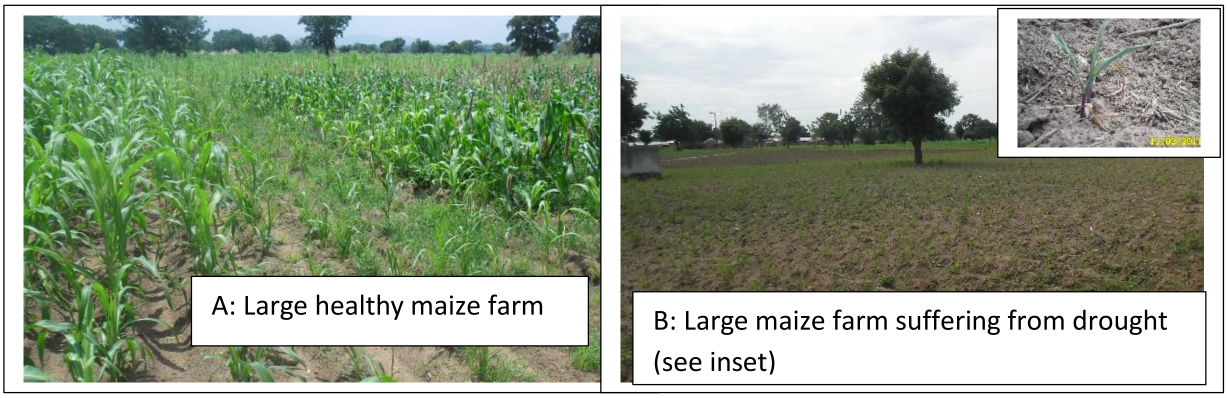


Fig. 4.5 Maize farms in the Upper East Region
Source (Taken by Author during filed studies)

In the group discussions, one participant in Bongo marveled how the climate has modified their food system. According to him, when they were children over 40 years ago, any family that ate food prepared with maize for their supper were considered to sleep without eating but now, nobody sees anything wrong with eating maize. According to him, their taste for food prepared with maize is even stronger as it is becoming a major crop.

However, in order to determine the effects of drought on crops, data at district level obtained from the Statistics, Information and Research Division of Ministry of Food and Agriculture (2013) were used. Data on five major crops (maize, rice, sorghum, millet and groundnuts) were extracted and used for the exercise. The yields (mt/ha)[14] were used for the analysis because it was believed that dividing the production (mt) by the area (ha) normalises the data and removes the effect of differences in area under cultivation (Simelton *et al.*, 2009).

[14] Mt = metric tons and ha = hectares

The yield data were then detrended using auto-regression (implemented in Excel) with a 3-year lag, in line with the method used by Simelton *et al*. (2009). This resulted in the loss of the first 3 years data and therefore the analysis was from 1995-2011. For simplicity, the districts that were created after 2004 were added to their parent districts since they did not have enough data for a time series analysis.

Auto-regression according to Simelton *et al*. (2009) removes the effects of increased technology and consistent misreporting. The removal of these effects then allows for the study of the effect of climate parameters on yield (Lobell *et al*., 2007, cited in Antwi-Agyei *et al*. 2012). The crop sensitivity index was derived from the crop failure index by dividing the predicted (or expected) yield by the actual yield (i.e. crop failure index= expected yield/actual yield) for each crop in each district. This resulted in values below one for years when the actual yield was higher than the expected yield, one when they were equal and above one when the expected yield was higher than the actual yield. The crop failure index was taken to be scores above one, representing years with actual yield below expected or predicted yield (Simelton *et al*., 2009).

In order to characterise the sensitivity of the crops, a score between 1 and 1.49 was categorised as sensitive, 1.5 to 1.99 very sensitive and 2 or above as extremely sensitive. The sensitivities of the crops also varied temporally and spatially for each crop and in accordance with the variations of the SPIs calculated above. Table 4.12 shows the sensitivities of the five major staple food crops grown in the districts. From the table, the crops are generally sensitive to climatic events but the sensitivities vary with the events, whether heavy precipitation (and subsequent flooding) or low precipitation (and subsequent drought) or both or even dry spells.

Table 4.12 Sensitivity of crops to events of droughts and floods in the Upper East Region

	Year																	
District	**crop**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Builsa	Maize			2		1			3	1		2	1	3				
	Rice	1	1	2		1	2	1						3		1	1	3
	Sorghum	1		1	2	2	1	1	1	1		1		3				1
	Millet	1		1		1			3	1	1	1	1	3				
	Groundnuts	2	1	1		1					1	1	1	1				
Kassena-Nan	Maize	1	1	3		1	2											
	Rice	1	1	2	1	1	2	2						2		1		1
	Sorghum	1	1	1		1	1	1		1				3				
	Millet			2		1	1	1	1					2				1
	Groundnuts					1	2	2			1			2				2
Bolgatanga	Maize		1	3	1	1					2	1	1	3	1			
	Rice	1	1	1	1	1			1	1	1			2		1		3
	Sorghum	1		1	1	2					2			2				1
	Millet			1	1	1	1	1			1			2			1	1
	Groundnuts	1	1	1		1	1					1		2		1	1	1
Bawku East	Maize	2	2	3	1	2				1	1		1	3	1			
	Rice		1	1							1	1	1	1				1
	Sorghum	1		1		1					3	1	1	3			1	1
	Millet		1	2		1		1			2		1	2	1		1	1
	Groundnuts		1	1		1				1	1		1	2		1	1	1
Bawku West	Maize	1		2		1	1					1		2				1
	Rice			1	1	1	1	1			2			1	1	1		1
	Sorghum			1		1	1	1			2	1	1	1		1		
	Millet			1		1	1	1			1		1	1		1		
	Groundnuts	1		1		1	1				1	1		1	1	1		
Bongo	Maize																	
	Rice	1	1	1		1	1	1			2		1	1				1
	Sorghum			1		1	1	1			1			1				1
	Millet			2		1	1	1			1		1	3			1	
	Groundnuts	1	1	1							1	1		2		1		1

Source (Based on Sensitivity values computed by Author)

N.B: 1=Sensitive; 2= highly sensitive; 3= extremely sensitive; empty space=normal

As can be seen in the Table, 2007 was an extremely sensitive year. It means that the combination of the drought in the early part of the 2007 season and the heavy precipitation in later part affected yields seriously. Thus the 2007 events did not only affect physical property and lives, they also affected crops. The years 1997, 2004 and 1999 events (in order of decreasing sensitivity) also affected all crops in the Region. In Bawku West, Builsa, Kansina-Nanakan and Bolgatanga, sorghum was most sensitive while in Bawku East and Bongo it was millet.

4.2.4 Susceptibility/impacts

As illustrated in the preceding sections, hazards are impacting heavily on the lives of the people as well as the ecosystem on which they depend. Crop failure or low yields means that there will not be enough food for the people. This is because majority of the people depend largely on their own production for household food consumption. As indicated in Fig. 4.6, about 84% of respondents rely on farm produce for household consumption.

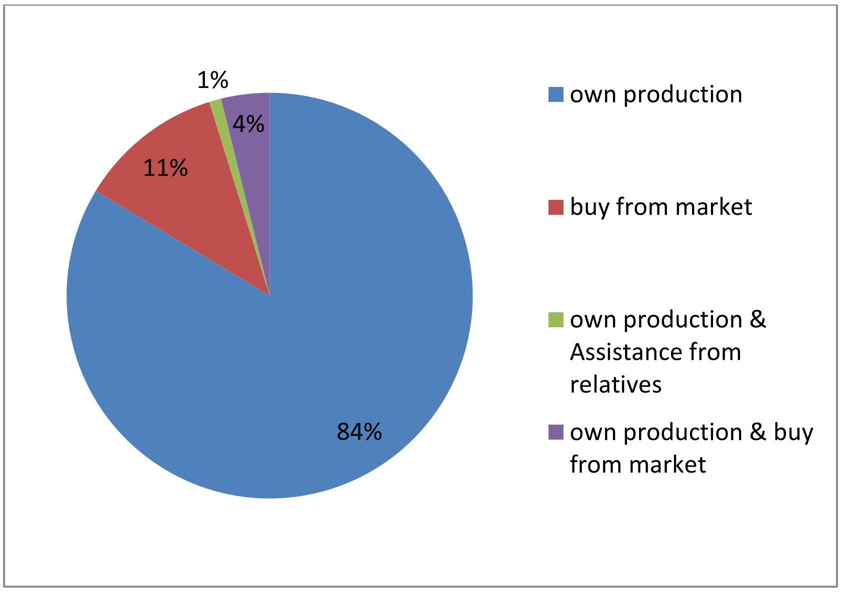


Fig. 4.6 Sources of Household food in the Region
(Source: Based on field studies by Author)

Low crop production also results in high food prices on the market and this may result in hunger, especially for the rural poor. A study by World Food Program (WFP) classified the Region as a food insecure Region (WFP, 2012) and this can be attributed to frequent losses in agriculture production locally resulting from these hazards. The 2007 crop failure, for instance, was largely due to floods and made the government of Ghana to declare the three Northern Regions as disaster prone and appealed to raise US$53 million for immediate needs; about 45% of the aid was to go to the Upper East Region alone (IRIN, 2014). Fig. 4.7 shows some of the impacts of the 2007 floods in Upper East Region where a whole maize farm was destroyed and a bridge cut off. This event together with the global food crisis in 2008 caused food prices to skyrocket almost on a daily basis, in the Region (Akudugu, 2010). Besides crop failure, the high temperatures in the Region also result in high evapotranspiration leading to the drying up of many surface water bodies. Liebe *et al*. (undated) found that, during the dry season from November to March, the daily rate of evaporation is between 4.9mm and 6.4mm.

Fig. 4.7 The effects of the 2007 floods in the Upper East Region
Source (www.ghanaweb.com)

This high rate of evaporation coupled with siltation render some of the small dams and dugouts unusable for the purposes for which they were built. The net effect of this is water scarcity for those who depend on surface water, contributing to shrinkage in size and death of animals. This is evident in Pwalugu, a community in the Talensi District, which has water problem because the village is on rocky ground and therefore a borehole cannot be sunk to harness groundwater. The respondents in this area all saw water crisis as their major problem. In an interview with a woman in this community, she said "in the dry season, we travel long distances to the valley close to the White Volta where we create wells to get water. The yield rate is very slow that we spend more time there and also the place can sometimes get crowded". According to her it even becomes worse when there is a drought. In all the focus group discussions, it was said that they are susceptible to bushfires because the high temperatures make the grass highly combustible. Bushfires have become an annual affair burning off both fauna and flora and therefore contribute to the deterioration of the ecosystem (Yiran *et al*., 2012). While bushfires were noted as a hazard, the study did not focus on them as they are not considered as natural hazards.

Sicknesses such as headache, cerebrospinal meningitis (CSM) and malaria were reported as being prevalent during the hot times of the year (Fig. 4.8). As can be seen in Fig. 4.8, virtually all who participated in the survey had fallen sick or had his/her relative fallen sick one or more of these illnesses within the last five years leading up to 2013. Heat related ailments (headache, CSM, body pains) were reported more than the flood related ailments (malaria, cholera, diarrhoea). This is due to the high temperatures recorded throughout the year (see Fig. 4.3 above). These illnesses could result in increased spending on medication and contribute to worsening poverty in the area. They also could affect labour output and contribute to low crop production. In 2012, the Region recoded 466 CSM cases with 38 deaths (Ghana Health Service, Upper East Region, cited in Reliefweb, 2012) and these represent reported cases. In the case of malaria, Table 4.13 presents a summary of cases between 2008 and 2010 indicating the burden of malaria in the Region.

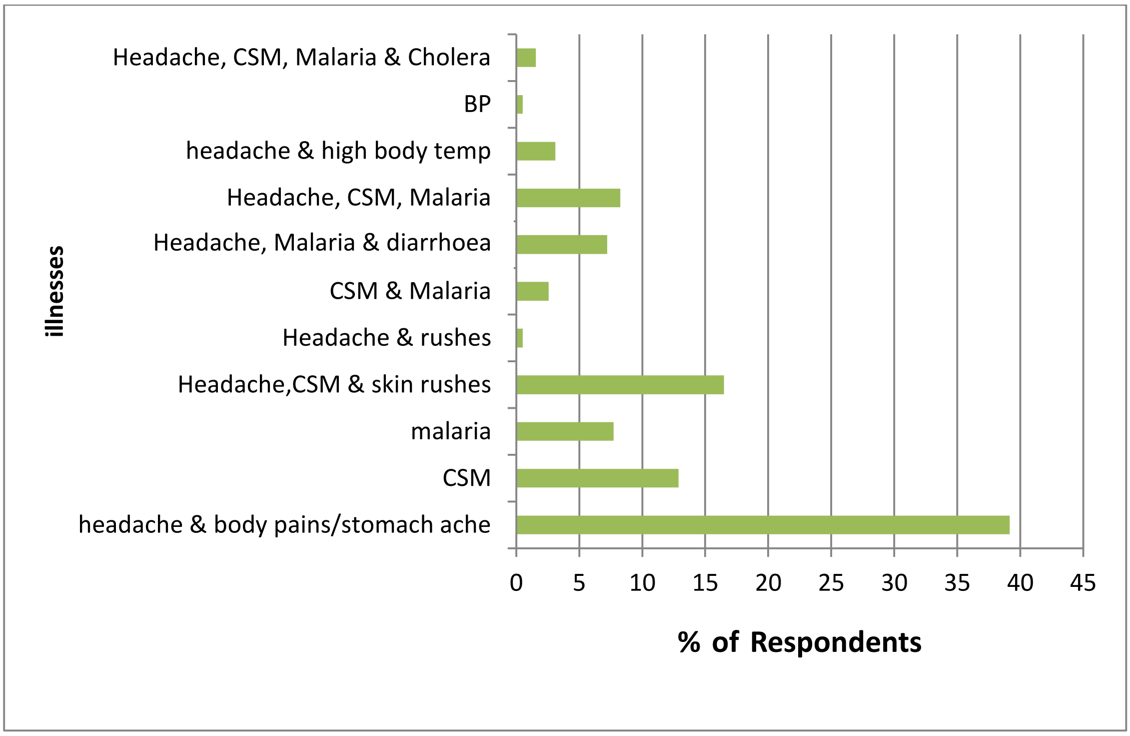


Fig. 4.8 Health effects of warming (high temperatures) on the inhabitants[15]
(Source: Based on field studies by Author)

Headache, CSM and malaria were found to be the commonest ailments plaguing the Region from the responses and the group discussions thus confirming these high values from the health records. In order to reduce the health risk, many of the respondents indicated that they work very early in the morning and by mid-morning, they retire to the shade, thereby reducing the effects of the scourging sun. This reduces the number of hours spent on the farm.

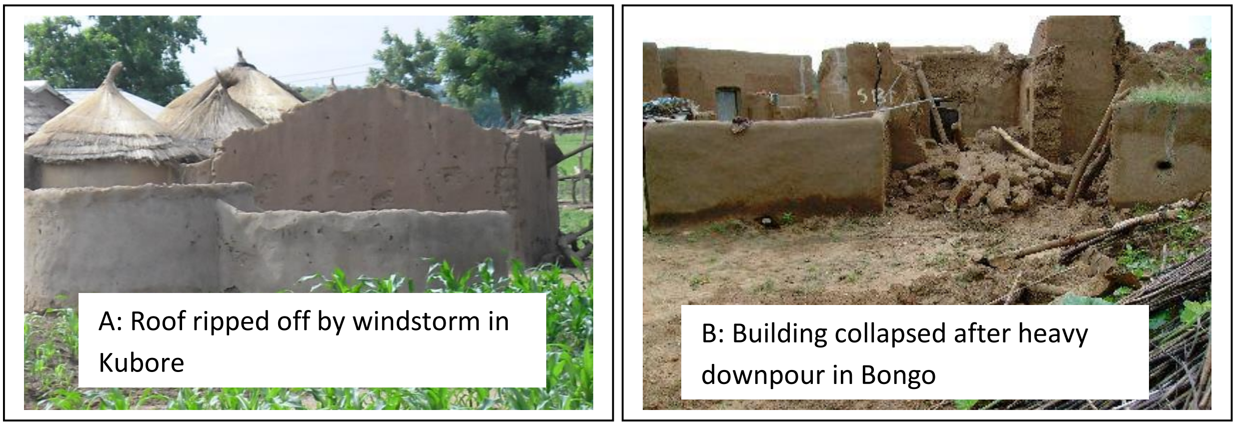
Table 4.13Malaria Burden in the Upper East Region

[15] BP is blood pressure and CSM is cerebrospinal meningitis. This was a multiple response question and the grouping was obtained from the responses

Indicator of burden	2008	2009	2010
% Out Patient Department attendance	53.2	56.5	53.3
% Admissions	40.9	41.6	41.1
% Deaths	52.6	51.1	41.7
% Under 5 Cases Fatality Rate	1.9	1.6	1.4
Over 5 Cases Fatality Rate	1.8	1.8	1.6

Source (Ghana Health Service, 2011)

Windstorms and heavy precipitation destroy homes and public buildings (Fig. 4.9). They rip off roofs and pull down trees, and in some cases, roofs are partially destroyed resulting in leakage during rains. When this happens, as gathered from both questionnaire survey and focus group discussions presented in the preceding sections, the people seek refuge with their neighbours until they are able to fix their rooms, and in some cases, public facilities such as schools and health facilities are closed down if they are hit by the storm. More than 92% of respondents have experienced the effects of windstorms in terms of their roofs being ripped off, of which 30% reported at least one room per season while the remainder do not experience this problem frequently but could not tell how often.



A: Roof ripped off by windstorm in Kubore

B: Building collapsed after heavy downpour in Bongo

Fig. 4.9 Effects of windstorms and heavy rainfall on buildings in the Region
Source (A: Taken by Author during field studies; B: downloaded from www.ghanaweb.com*)*

4.3 Summary

This chapter set out to investigate the hazards and the trends in the area over the study period. Guided by the framework shown in Fig. 4.1, data from GMet, MOFA, Ghana Health Service as well as the field survey and other published documents were used to achieve this. The five hazards, droughts, high temperatures, floods, heavy rainfall and windstorms, identified by the respondents, were confirmed to be occurring in the Region according to the SPI and analysis in Excel. These climatic hazards occur frequently and more often than not, more than one hazard occur in the same season. Drought events occurred 9 times at Binduri, 10 times at Manga, 12 times at Navrongo and 13 times in Vea. The number of times the drought events occurred at each station seems to be the same before and after 2000 but the magnitudes were higher in the 2000s than the 1990s.The frequency and intensity of dry spells were more after 2000 than before 2000. The floods/heavy rainfall events have occurred about 7 times in all stations but have increased in frequency and impact more after 2000 than before 2000. The consequences of floods are exacerbated by the opening of or spill-over from dams in Burkina Faso and by a tendency to locate human activities in flood prone areas. The hazards occur in different years/seasons and times of the season at each station though some have occurred in same season/time.

The people and the ecosystem are sensitive to these hazards. The climatic hazards affect many aspect of their lives. Agricultural productivity is low due to these hazards, while they battle to maintain their physical properties and their health is not spared. They also have to contend with a water scarcity situation and the destruction of their land and environment by these hazards. However the people continue to live and eke a living in the Region. Thus the next chapter is devoted to study how the people manage to eke a living in the face of these hazards.

Chapter 5 Determining adaptive capacities

5.1 Introduction

As the people and the ecosystem on which they depend repeatedly encounter hazards and their deleterious effects, they have over time found ways of responding to them. This chapter investigates how the people in the Region have over the past 30 years (1983-2012) responded to these hazards, with a view to identify their adaptive/coping capacities. This will aid in the indicator development in chapter 6. In the present chapter, the shaded (gray) portion of the conceptual framework in Fig. 5.1 will be considered in order to analyse the adaptive capacity of the Region.

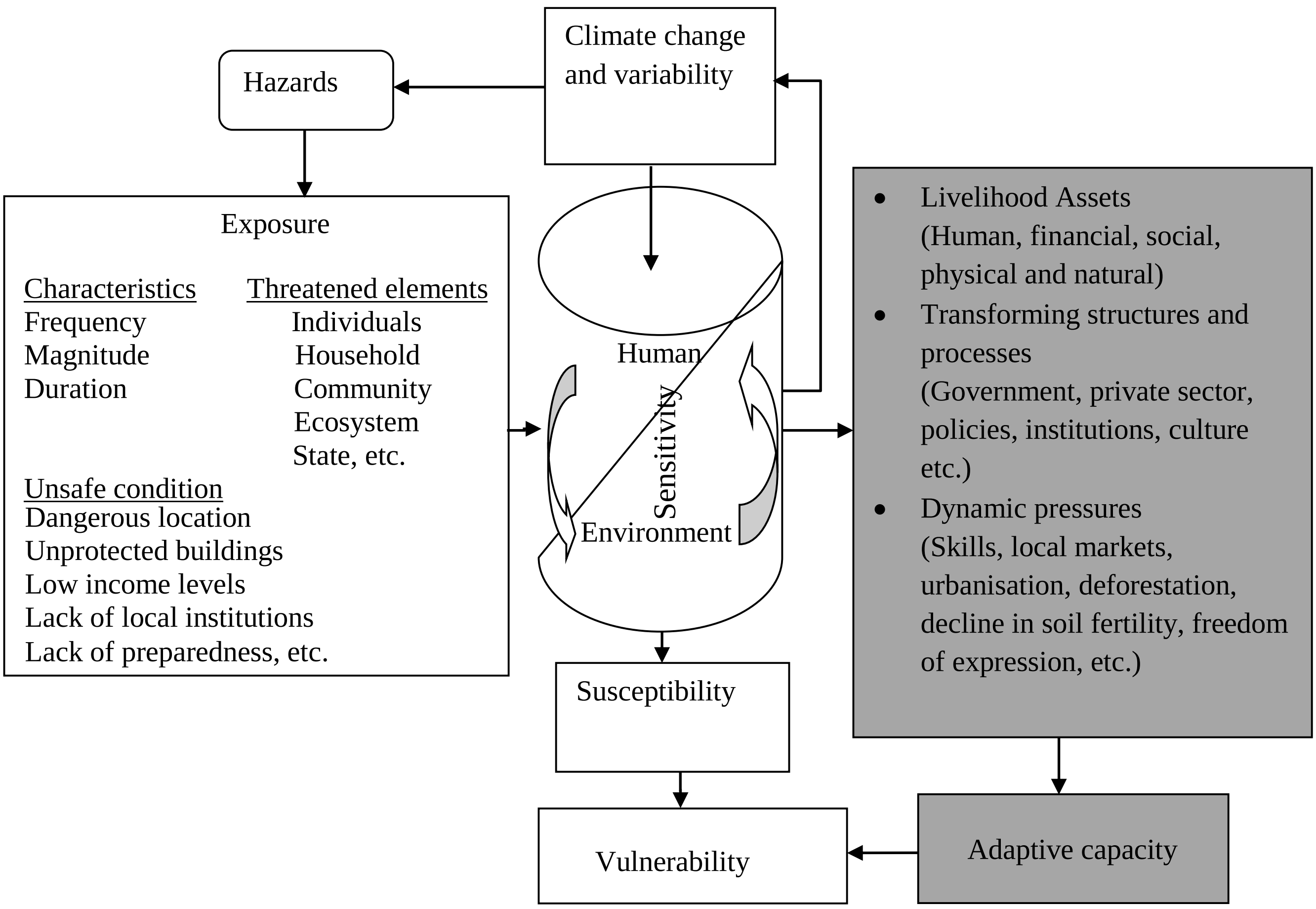


Fig. 5.1 Aspects of the conceptual framework for analysing adaptive capacity
Source (Author's own construct)

The data to be used for this analysis were drawn from the questionnaire survey, focus group discussions, photography, and secondary sources, particularly the 2010 population and housing census, 2008 demography and health survey, World Food Program (WFP) as well as health service reports and other published documents. The chapter is divided into sections that discuss livelihood assets, dynamic structures, transforming structure and processes and other coping strategies presented in the shaded (gray) portion of Fig. 5.1.

5.2 Livelihoods assets

Livelihood assets according to DFID (1999) comprise five capitals: natural, physical, human, social and financial (cited in Kemp-Benedict, 2009). The argument is that people/communities with a wide range of assets or resources have many choices to make and are better able to adapt to hazards than resource poor communities (Fraser *et al*., 2011, cited in Dixon *et al*., 2014).

5.2.1 Natural capital

The main natural capital available in the Region is land and it is accessed largely by inheritance. The type of inheritance practiced here is the patrilineal, where a male parent bequeaths his land/property to his male children (Yiran *et al*., 2012). From the survey, more than 65% of respondents got access to land through inheritance. The rest got their land from borrowing, buying or renting. Women acquired land from their husbands or by borrowing, buying or renting. Under the prevailing patrilineal system of inheritance, the land is divided among the male children. This has resulted in a chain of divisions from their ancestors to the present generation. As population grows, there will come a time when the land will be insufficient to support the family. Some families have started experiencing this already and have harnessed extra land through borrowing, renting and buying. Though those buying especially for agricultural purposes constituted a minute proportion (0.1%) of the sampled population, it shows that land is becoming a scarce resource and that commercialisation of land has set in (Tsikata and Yaro, 2011). The population density of the Region has increased from about 104 persons/km^2 in 2000 to about 119 persons/km^2 in 2010 (Ghana Statistical Service, 2012b).This means that land holdings per capita are decreasing. The land is also becoming less productive. This aspect is explored further in the section on dynamic pressures.

5.2.2 Financial capital

The land is the base for most of the economic activities in the Region. The largest economic activity is agriculture which as mentioned earlier, largely comprises subsistence farming. The majority of the crops produced, especially by rural farmers is for household consumption, and therefore very little or nothing is sold. People in the Region therefore remain poor as they have very limited alternative livelihood options in order to move themselves out of poverty. According to the Ghana Demographic and Health Survey, about 84% of the residents in the Region fall within the two lowest wealth quintiles, with about 65% of these in the rural areas (Ghana Statistical Service *et al*., 2009). The wealth status of the Region is low because of the over reliance on agriculture which is still not commercialised, and because more often than not, it faces challenges with the weather and poor soil fertility. The Region has some gold deposits in the Bolgatanga Municipality, Bawku West, Nabdam and Talensi Districts and these provide for small scale mining/*galamsay* activities. There are also quarrying activities in Bongo and Talensi Districts (Ghana Statistical Service, 2012a).Other areas in Bawku and Builsa Districts have some clay deposits used in the pottery and building industry. These provide opportunities for investments as well as alternative sources of income for the people. According to the 2010 housing and population census, about 445,770 people out of the 1,046,545 in the Region were employed as at 2010 in various activities, as shown in Table 5.1.

Table 5.1 Employment status

Employment/job	**Number**	**Percent**
Manager	4,483	1.01
Professional	13,045	2.93
Technical and associate professionals	3,544	0.80
Clerical support workers	2,853	0.64
Services and sales workers	44,034	9.88
Skilled agricultural, forestry and fishery workers	312,546	70.11
Craft and related trades workers	44,489	9.98
Plant and machine operators and assemblers	8,937	2.00
Elementary occupations	11,654	2.61
Other occupations	176	0.04
Total	**445,770**	**100**

Source: Ghana Statistical Service, 2012b)

Agriculture and its related activities contributed more than 70% of the labour force (Table 5.1). However, agricultural productivity in the Region is low resulting in low income and partly accounts for the high level of poverty (Ghana Statistical Service *et al*., 2009).More than 98% of respondents in the questionnaire survey kept some form of livestock ranging from a few fowls to cattle. The numbers and type vary depending on financial capital and the ability of the household to take care of the animals. In the group discussions, particularly those held in the rural communities, it was mentioned that the individual holdings of animals under the traditional free range has reduced because families hardly get surplus yields that they can sell to finance the purchase of more animals. They would rather sell the existing ones to buy food. The animals also die due to disease and a lack of pasture and water. Low yields therefore also affect the acquisition of other assets. This leaves people with very limited financial capital and therefore very few choices to manage their increasing exposure to hazards.

Because land in the area is communally owned where individual land rights are restricted and benefits shared among family members, so investments necessary for intensive agriculture are not made (MOFA, 2007). Low investments affect agriculture infrastructure and the management of these infrastructure in the Region. The management issue cropped up in the focus group discussions at Kumpalgoga where there is a dam that is not being used due to interference from the family who owns the land around it. The participants in focus group discussion said dam is left to silt. Participants agreed to the need to de-silt the dam and to put it to proper use, but were quick to point out that before de-silting, it will be better for the investor to sit with the community members and the family to draw up some kind of usage rights agreed on by all parties to avoid future interference.

Although there are banks in the big towns and other financial institutions, only a few individuals with business acumen could access these facilities. Most people do not have the collateral required by the banks to access the loans. Only19% of respondents have borrowed money from these banks. In the WFP report, the banks are not lending to the farmers because of high rates of defaulting (WFP, 2012). However, in the Binduri and Garu-Tempane districts, it was mentioned that BESSFA[16] (a rural bank) registers the farmers in groups and supplies the groups with farm inputs. The groups repay the loans after harvest. This exercise is yielding positive results as farmers in these areas largely get greater harvest than their counterparts in other districts (Table 5.2).It can be seen that farmers in Kumpalgoga had good harvests compared with their counterparts in the other sampled villages. The relatively good harvests in Kumpalgoga were attributed to the assistance with farm inputs from BESSFA. In other areas, some people harvested more than 20 bags but these people had other sources of income, for example, being teachers or people in formal employment who

[16] BESSFA is Bawku East Small Scale Farmers Association.

used their income or could get loans from banks to invest in farming using their employment status. The remaining 10 respondents were not into serious farming and therefore had one bag or less. Besides helping farmers, BESSFA also assisted traders in these communities by registering them in groups and giving them financial assistance. According to these traders who were largely women, every market day, they make repayments of the loans. If anybody in the group is defaulting, that person alerts the group as to the reason why she is defaulting. Then, she is given the chance to make up the loan repayment on the next market day.

Table 5.2 Harvest of the major crop in year of good rain[17]

	Harvest in normal year							
Town/ village	**two bags**	**five bags**	**ten bags**	**fifteen bags**	**cannot estimate**	**20-50**	**more than 50**	**Total**
Bawku	2 (11)	4 (22)	3 (17)	6 (33)	1 (6)	2 (11)	0	18
Bolgatanga	0	7 (33)	11 (52)	3 (14)	0	0	0	21
Bongo	3 (21)	8 (57)	1 (7)	1 (7)	0	1 (7)	0	14
Fumbisi	6 (40)	8 (53)	0	1 (7)	0	0	0	15
Tempane	1 (7)	1 (7)	4 (27)	2 (13)	0	6 (40)	1 (7)	15
Koose	0	2 (13)	8 (53)	4 (27)	0	1 (7)		15
Kubore	1 (7)	6 (40)	6 (40)	1 (7)	0	1 (7)		15
Kumpalgoga	0	0	1(7)	1 (7)	0	11 (73)	2 (13)	15
Nangodi	1 (7)	4 (27)	8 (53)	1 (7)	0	1 (7)		15
Navrongo	3 (23)	2 (15)	5 (39)	1 (8)	0	2 (15)	0	13
Pwalugu	0	5 (39)	6 (46)	0	0	2 (15)		13
Saboro	0	4 (29)	4 (29)	2 (14)	0	4 (29)	0	14
Sandema	7(47)	7 (47)	1 (7)	0	0	0	0	15
Total	24(12)	58(29)	58(29)	23(12)	1 (1)	30 (15)	4 (2)	198

(Source: Based on field studies by Author) N.B: Numbers in brackets are row percentages

5.2.3 Social capital

The groupings (farmer groups and market women associations) mentioned above and collective activities not only boost economic activities of the people but also help them care about their members, such that if one is not at market, the other members will go to her to

[17] Normal year refers to a year with normal rainfall. A bag refers to the 100 kg sack. Major crop is either maize, millet or sorghum

find out the problem and see what help they could offer. It was gathered that sometimes they contribute money and other items for group members who are in need or bereaved. Similar groupings existed in some other communities where group members could contribute farm labour to members and offer helping hands in times of need, especially when hit by a hazard. The participants in the group discussions said they often assisted to reroof after roofs had been ripped off by winds.

Other social networks that are important to the people are the family (extended), neighbours and friends. These social networks are called upon when there are hazards or disasters. They come together to contribute to support the hard hit. Their contributions include money, food items, labour to reconstruct, and sometimes provision of temporary accommodation. All in the questionnaire survey who provided assistance admitted their help was insufficient to cover the loss but indicated that it cushioned the initial shock. They added that it provided psychological ('mental') relief to the afflicted and kept them together as a family or community. Another form of assistance is coming from remittances from relatives living outside of the communities. About 78% of respondents whose relatives live elsewhere received remittances, and in many cases, these remittances increased in times of hardship.

Though the majority (57.5%) of respondents indicated having to deal with the major effects of floods for instance by themselves, some of these social networks play important roles in surviving the hazards. Table 5.3 indicates how the respondents whose properties were affected during the last major flood event (in 2007) survived and coped with the losses. In all, about 34% of respondents used remittances and/or sought help from neighbours during and after this flood event as a means of getting the basic needs for life. Similarly, social networks are put to use for the other hazards, particularly following destruction of homes due to heavy rainfall and windstorms.

Table 5.3 Strategies for recovery from major flood events

	Sources/ strategies								
Town/village	Remittances	Assistance from neighbours	survived on own resources	survived on own & Gov't assistance	Options in Col 1 & 2	Not affected	Sold livestock/ fishing	Other farm produce and/or animals	Total
Bolgatanga	8 (33)	4 (17)	9 (38)	0	0	3 (13)	0	0	24
Bongo	0	0	4 (67)	0	2 (34)	0	0	0	6
Fumbisi	7 (47)	0	7 (47)	0	0	1 (7)	0	0	15
Kayoro	0	0	15 (100)	0	0	0	0	0	15
Kubore	2 (20)	0	8 (80)	0	0	0	0	0	10
Kumpalgoga	1 (7)	0	10 (67)	0	0	0	2 (13)	2 (14)	15
Nangodi	0	0	12 (92)	1 (8)	0	0	0	0	13
Navrongo	2 (20)	5 (50)	1 (10)	0	2 (20)	0	0	0	10
Pwalugu	2 (13)	0	13 (87)	0	0	0	0	0	15
Sandema	9 (64)	2 (14)	1 (7)	0	1 (7)	1 (7)	0	0	14
Tempane	3 (23)	0	6 (46)	2 (15)	1 (8)	0	1 (8)	0	13
Total	34 (23)	11 (7)	85 (58)	3 (2)	6 (4)	5 (3)	3 (2)	2 (1)	150

Source (Based on field studies by Author). N.B: Number in brackets represent percentages. Options in col 1&2=remittance and assistance from neighbours.

In these instances, in addition to strategies mentioned in Table 5.3, others offered temporary accommodation to their neighbours or family members whose houses/rooms were destroyed. Some also assisted in evacuation of the weak and in contributing labour to rebuild or roof the affected rooms.

5.2.4 Human capital

Although the people are financially poor, their experiences have given them tremendous knowledge which can be useful in dealing with the challenges (Dixon *et al*., 2014). One such strategy gathered from the people (especially the farmers) is weeding/hoeing around the crops early morning. This, according to them, spared the roots of the young crops from the scourging sun. It also helps the crops to withstand the dry spells for a reasonable time before withering. They found that when there is a drought or dry spell, weeding between 11:00am and 3:00pm puts hot soil round the roots and the stem which burns and kills the crops. They also realised that the water below the surface soil evaporates faster because the soil is loosened and the heat from the sun is able to penetrate deeper. Though the mid-day rest reduces the number of working hours they need on their farms, to them, it is better. As one farmer in Tempane puts it, "it is better to save a little than to spend the whole time weeding and lose everything".

In Kubore in the Bawku West district, some farmers mentioned planting of crops after the floods (similar to flood recession farming). Thus, the flooding could become something good for agriculture if this is practiced on a wider scale but will require a study to determine the duration of moisture in the soil after the water has receded completely since this is usually towards the end of the rainy season. This will provide a basis for the introduction of crops that can survive the duration of the moisture so as to increase production particularly around the flooded areas. In addition, the questionnaire survey also found the options in Fig 5.2 being practiced by the respondents in the various communities which vary significantly statistically with a p-value of 0.001 using chi-square test. The majority of the respondents do nothing when there is a drought. It is evident from Fig. 5.2 that the people have very limited options to take when a drought occurs in terms of their human capital. This could be attributed to the low level of education or high illiteracy level in the Region. As illustrated in chapter 3, only 41% of the people age 14 and above can read and write in English, the official language of doing business in the country. This explains why more than 70% (Table 5.1) of the work force are employed in agriculture and related activities, as these require no skill except what has been handed over by their fathers. Thus, the Region has a vibrant work force but is largely unskilled.

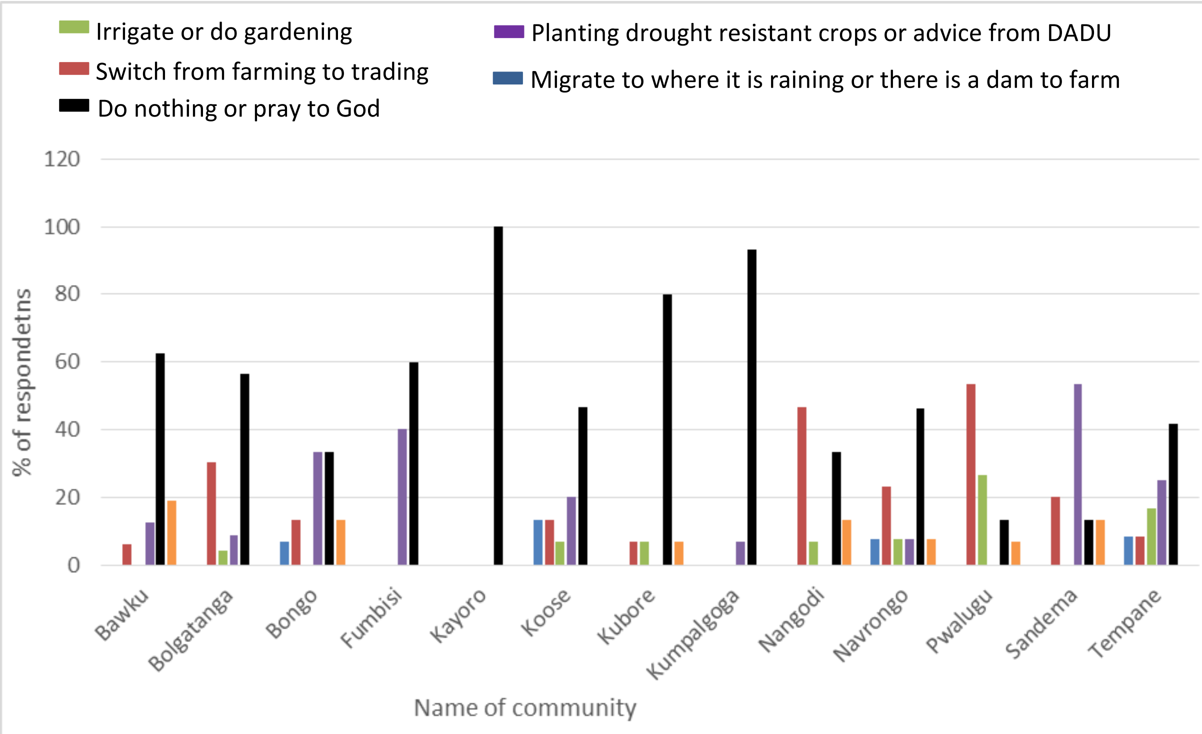


Fig. 5.2 Responses to drought by respondents
Source (Based on field studies by Author)

5.2.5 Physical capital

Not only are human capital levels in the Region very low, but the infrastructural development is also low. As noted by Satterthwaite (2008:4), "for any city, the scale of the risk from extreme weather events is much influenced by the quality of housing and infrastructure in that city, the extent to which urban planning and land-use management have successfully ensured risk reduction within urban construction and expansion, and the level of preparedness among the city's population and key emergency services". The physical capital was analysed with some of these key points in mind.

The majority of the housing units in the rural areas are built with mud/earth materials and roofed with thatch or mud. The mud has no cementing material and therefore the houses are easily destroyed by floods, windstorms and heavy rainfall, especially when the ground becomes too wet. Observations made on the buildings showed that they are structurally weak and therefore unable to withstand heavy rainfall which makes the ground wet or waterlogged. As can be seen in Fig. 5.3, the buildings have no foundation and are just sitting on the ground, so when the ground becomes soaked with water, the base of the buildings becomes weak and cannot support the weight it is carrying and hence gives in.

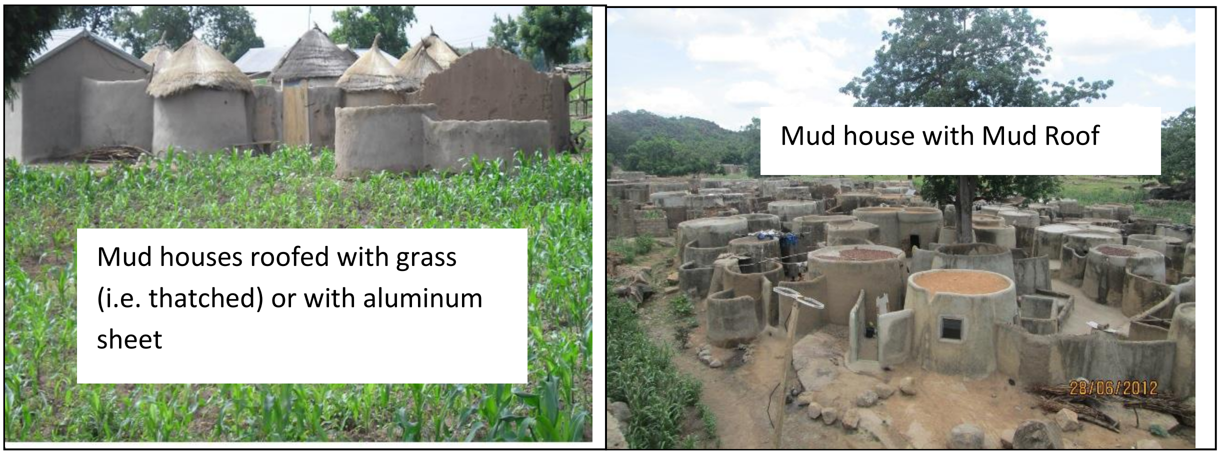


Fig. 5.3 The nature of rural houses
(Taken by Author during field studies)

This was confirmed by the participants during the group discussions they do not construct foundation before building and the mud used are not also compacted nor have any cementing added before building. They just mix the soil with water and build. According to participants in the focus group discussions, the thatch is bound with jute and when the jute rots or gets soaked by rain, they are easily blown off by a strong wind. However, a greater majority of housing units in the urban area are built with concrete material and roofed with roofing sheets and are much stronger (Fig. 5.4). The urban houses can withstand most of these hazards to a greater extent than the rural dwellings because they are constructed with higher quality material and are also built on concrete foundations. In Fig. 5.4, the ground, as well as the building's foundations are wet, yet these buildings do not collapse. If the rural type of houses were found here, they would have collapsed in no time. Fig. 4.9 (in section 4.2.4 of chapter 4) shows an example of a rural house that collapse after one heavy downpour.

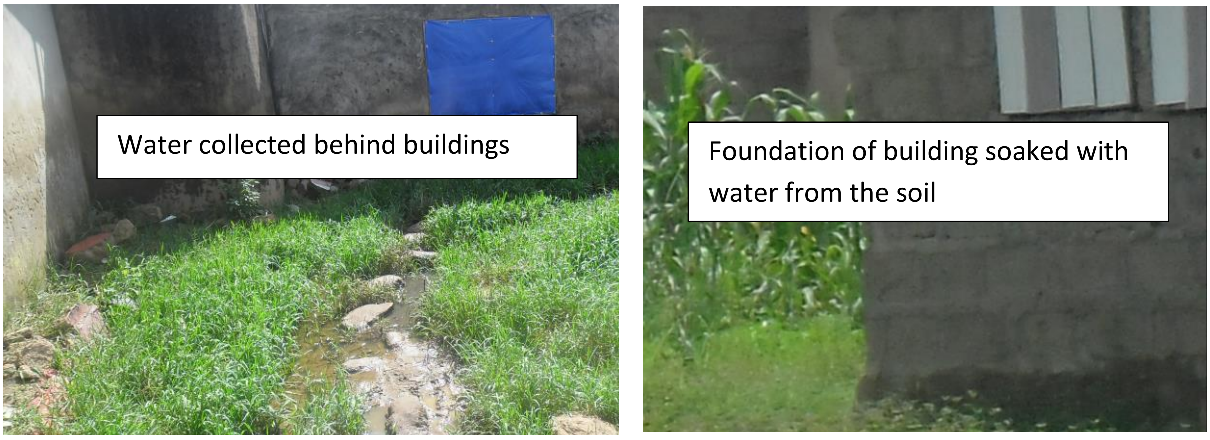


Fig. 5.4 Houses built in waterlogged areas in Bolgatanga
Source (Taken by Author during field studies)

The respondents attributed the increase of buildings in areas with similar soil characteristics as in Fig. 5.4 to increasing demand for housing and the scarcity of safer lands in the urban towns. Other studies in urban areas had similar findings (e.g. Oteng-Ababio, 2011; UN-Habitat, 2011). An attempt was made to gather information about the structural strength of the different type of housing but talking to architects and quantity surveyors, it was realised that no systematic study has been carried out to determine the strength of the mud houses. As such, the strengths of these buildings were assessed qualitatively based on which type is stronger or weaker. However, the housing units built with concrete and roofed with metal sheets pose a health risk to the people as they retain heat longer than the mud/thatch ones.

Besides the housing units, there are other buildings which serve administrative, health, education and other purposes which enhance the lives of the people. The Region has about 178 health facilities with a breakdown as shown in Table 5.4. Districts with hospitals are those that existed before 2004.

Table 5.4 Health facilities

Municipality/District	Hospital	H/C[18]	Clinic	CHPS	Maternity Home	Total
Bawku	1	6	9	10	1	27
Bawku West	1	3	9	10	0	23
Bolgatanga	1	2	10	6	0	19
Bongo	1	4	2	13	0	20
Builsa	1	4	2	11	0	18
Garu-Tempane	0	6	5	5	0	16
Kasena-Nankana East	1	2	2	16	0	21
Kasena-Nankana West	0	3	2	11	0	16
Talensi-Nabdam	0	3	6	9	0	18
TOTAL	**6**	**33**	**47**	**91**	**1**	**178**

Source: Ghana Health Service (2009)

These health facilities, inadequate as they may be, are under staffed. Statistics from the Regional health directorate indicate low staff-patient ratios (Table 5.5). These figures are an indication of the larger problem of health service provision in the Region.

Table 5.5 Critical Health Staff to patient ratio

Staff category	Ratio
Doctor	1:34,044
Pharmacist	1:79,827
Midwife	1:4,895
Medical assistant	1:33,476

Source (Ghana Health Service, 2011)

[18] H/C = Health centre and CHPS = Community-based Health Planning andServices

Thus, the state of health provision is not good in the face of the increasing hazards in the Region. On road infrastructure, with the exception of the roads linking the urban towns and some few in the urban centres which are tarred, all other roads are feeder roads, tracks and footpaths. The Bolgatanga-Bawku and Navrongo-Sandema roads have become bad recently. The feeder roads also get eroded during the rainy season with some rendered not motorable. These roads are supposed to be used to convey goods and services as well as people to various places. Because of the numerous and dangerous potholes on the road, the cars sometimes use the shoulders of the road as can be seen in Fig. 5.5.

Fig. 5.5 Potholes on the Bolgatanga-Bawku Road
Source (Taken by Author during field studies)

The deplorable nature of the roads especially during the rainy season makes travel expensive in terms of time and money. For example, it was observed by respondents that the travel time from Bolgatanga to Bawku which used to be about 30 minutes to one hour has doubled or tripled in the last two or three years. This, according to the respondents, has increased the cost of doing business between the towns. The feeder roads suffer greater from erosion and waterlogging. These are also used to convey sick people to the health facilities and also to distribute relief items to victims of disasters and increase the cost of delivery of these services as well as travel to the urban areas.

In recognition of the increasing threats of drought, the government in collaboration with NGOs and donor agencies, have constructed over 200 dams/dugouts throughout the Region (GIDA, 2013). There are two big dams: Tono and Vea dams managed by the Irrigation Company of Upper Region (ICOUR); the rest are managed by the communities (GIDA, 2013). The two big dams are used for large scale irrigation farming, particularly rice and vegetable production, though their irrigable areas are not fully used (Namara *et al*., 2011). The smaller dams and dugouts are used for gardening and watering of animals and in some cases for domestic purposes (GIDA, 2013). Largely water for drinking is obtained from ground water through boreholes and wells. In some few cases, particularly in Binduri, Garu-Tempane and Bawku West Districts, groundwater from riverbeds and valleys close to rivers was harnessed for vegetable farming.

As can be seen in Fig. 5.6, the total percentage of respondents who use groundwater for irrigation or dry season gardening is higher than surface water. The water sources in Fig. 5.6 include well, borehole and river (i.e. water from the riverbed).

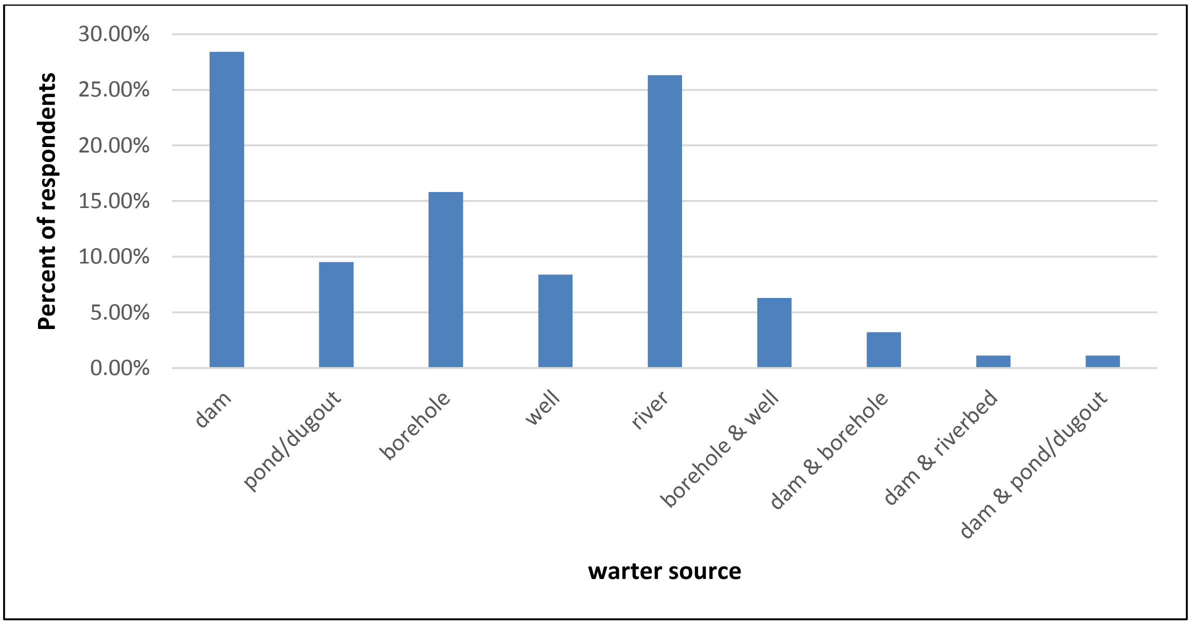


Fig. 5.6 Source of water for dry season farming or gardening
Source (Based on field studies by Author)

Majority of the rivers in the Region are dry in the dry season and therefore water from them is usually harnessed by wells (holes) dug in their beds. Namara *et al*. (2011) found that groundwater is becoming an important source for dry season farming and this confirmed in the findings here. Although groundwater is being used by many people, surface water still remains the source for large scale irrigation and commercial farming producing more than 80% of the irrigated produce in the Region(MOFA, 2010). This means that groundwater is used largely by smallholder farmers as observed from the responses from the fieldwork and focus group discussions. Crops produced from the dry season farming are vegetables such as tomatoes, pepper, onions and leafy vegetables and fruits such as water melon and yellow melon. It was also mentioned that the maize varieties being cultivated are improved varieties and short maturing ones. Thus, technology though low is improving in the area. The low level of adoption of technology in the Region was attributed to the low level of literacy.

The educational infrastructure is expanding and has led to almost every community in the Region having a school (Ghana Statistical Service, 2012b).This development may improve the literacy level in the near future and give the Region a positive outlook, at least moving away from dependence on subsistence agriculture to mechanised agriculture and other livelihood activities. Despite their high illiteracy rate, those engaged in dry season farming are seeing it as a positive development as it increases their incomes. About 92% of these people see it as an excellent measure against drought as they sometimes earn more from dry season farming than the normal rainfed farming.

However, their major problem with vegetable production was marketing as the crops they produce are perishables. The participants in the focus group discussions said they do not have the power to determine the prices of their produce. Prices are dictated by the buyers and in years of bumper harvests, they get very low prices for their produce, thus leaving them still very poor. The market centres are also located at varying distances from the locations of the farmers and they use various means of transport (Table 5.6) depending on ability to pay and availability of the means. For the peasant farmers who do not produce in large quantities, they will have to convey their produce to the market to sell and most do this by head.

Table 5.6 Means of carting produce to the market

Mode of transport[19]	**No. of respondents**	**Percent**
Head portage	54	26
Bicycle	13	6
Motor bicycle	3	1
Motor king	20	10
Public transport	25	12
Donkey cart	15	7
A combination of two or more modes	44	21
Other 1	2	1
Other 2	32	15
Total	208	100.0

Source (Based on field studies by Author)

Only 1%of the interviewees were commercial farmers and their produce was bought and picked from the farm while 15% produce mainly for home consumption and therefore do not sell at all. The majority (26%) cart their produce to the market on their heads which shows low level of access to public transport in the Region. That is, the vehicles are not readily available and are also expensive to afford by the peasant farmers. The markets where the farm produce is sold are located in distant towns/villages or in the district capitals. As can be seen in Fig. 5.7, more than 50% of respondents sell their produce in towns/villages

[19] Other 1 represent farmers who sell their produce on the farm and other 2 represents those who do not sell

more than 2km away from their locations. Although every town/village has a market, the major markets in the Region are those in Bolgatanga, Bawku, Zebilla, Navrongo and Sandema. Thus, the people convey their goods to these markets every 3 days to sell and these markets and other markets are several kilometres away from most of the towns/villages. They therefore depend on the deplorable transport system to carry their goods to these big market centres.

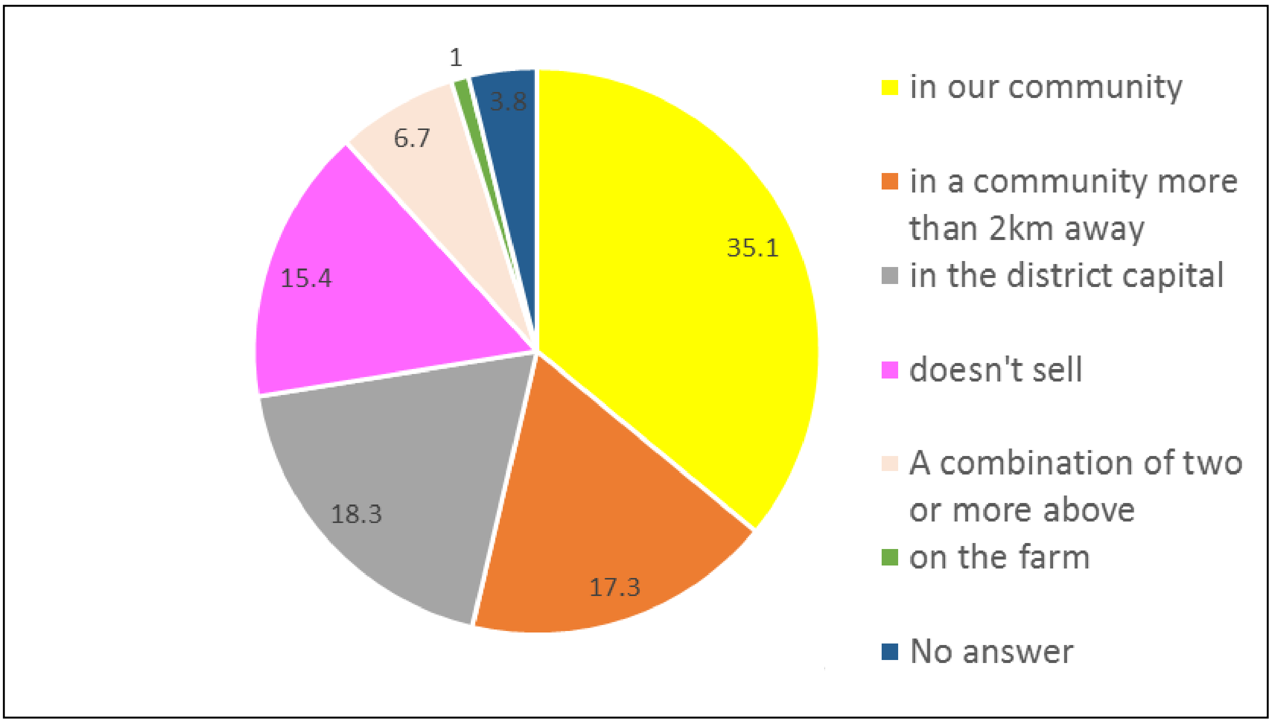


Fig. 5.7 Location of market centres where produce from farms are sold
Source (Based on field studies by Author)

5.3 Dynamic pressures

The dynamic pressures as captured in the pressure and release model (Blaikie *et al.*, 1994, cited in Cutter *et al.*, 2009) translate economic and political processes into local circumstances. The important elements of the dynamic pressures essential for this work include lack of skills and investments, rapid population growth, urbanisation, deforestation and soil fertility loss (see Fig. 5.1). However, lack of skills and investments have been captured in the livelihood assets in the preceding section. Therefore, this section will concentrate on rapid population growth, urbanisation, deforestation and loss of soil fertility. The increase in population puts more pressure on the land leading to the use of marginal land for livelihood activities. This means that increasingly, human activities will be located in dangerous or unsafe places, thus increasing exposure to hazards. As the Region's population increases, so does the urban population which has increased steadily at an average intercensal rate of 1.4% (Ghana Statistical Service, 2012b). This has resulted in rapid urbanisation in the towns and even clustering of some rural communities into towns or urban centres. Thus, the 2010 population and housing census has more urban towns in the Region than previous censuses (Ghana Statistical Service, 2012a) but this will become more apparent showing which villages have become towns or urban centres after the release of the district level analysis. Fig.5.8 shows the proportion of urban population for the various censuses. It is clear that the Region is urbanising as the proportion of urban population is increasing.

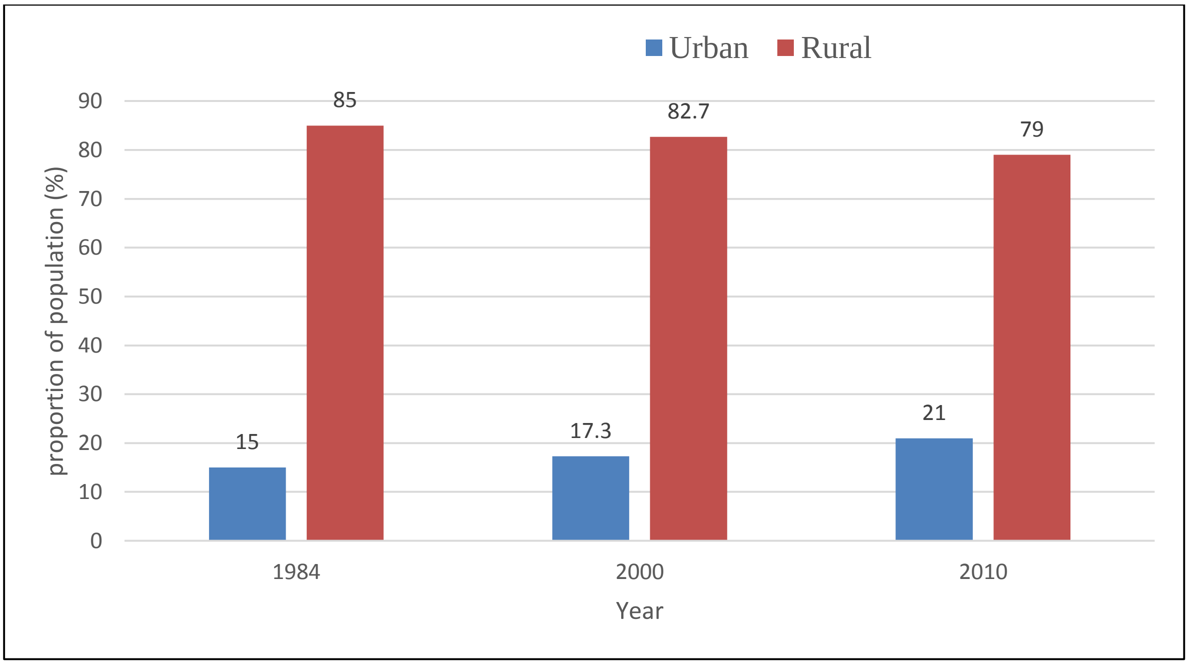


Fig. 5.8 Proportion of rural and urban population according to years
Source (Ghana Statistical Service, 2005, 2012b)

The number of houses increased by 29% from about 80,965 in 2000 to 114,034 in 2010 (Ghana Statistical Service, 2012b). Urbanisation in relation to hazards is a problem as it increases the use of unsafe lands for human habitation, thus exposing them to hazards. This is more so in urban areas where buildings are put in areas as shown in Fig. 5.3. Not only is population growth putting demand on land for housing units, it has also led to the continuous use of the land for farming and other activities. These activities are believed to be contributing immensely to land degradation, which is manifested in the form of soil erosion, soil fertility decline, soil compaction, reduction in grassland/vegetal cover among others (O'Heringis, 2005;Senayah *et al*., 2005; Gyasi *et al*., 2006; Yiran *et al*., 2012). Studies such as those stated above and many others on environmental change in the Region have reported a decline in vegetal cover and soil fertility and have attributed that to extension of farmland and continuous cultivation. In all the focus group discussions, it was stated that land is hardly fallowed and therefore without fertilizer or manure, yields are very low. However, the cost of fertilizer is high and not all of the people are able to afford it and apply in the right quantities to obtain good harvests. This explains why those who got assistance with farm inputs got more yields than those who did not have assistance.

5.4 Transforming structures and processes

The difficulties enumerated in the preceding sections require stronger structures and processes such as the government, private sector, institutions, culture and policies to transform them in order to better the lives of the people and sustain development. The government operates a decentralised system of governance through the local government structure at the district level. Most of the state run institutions also follow a decentralised approach. By this, each of the institutions has a Directorate or Division or Department at the district level. The local government structure at the district level is the District Assembly

System, comprised of two-thirds of elected and one-third government appointed assembly members, a District Chief Executive (DCE) appointed by government and the elected member(s) of parliament in the district (1993 Local Government Act (Act 462), cited in Akramov and Asante, 2009).

The District Assembly is in charge of the day to day running of development programmes and implementing government policies at the local level. The government institution affiliated with the District Assembly in charge of disasters is NADMO which was established in 1995 (The World Bank Group, 2009). The District Agricultural Development Unit (DADU), is in charge of agricultural development in the districts. The efforts of these government institutions are supplemented by NGOs such as ACDEP, World Vision International, Action Aid, Red Cross, etc. in the area of disaster management and agricultural development.

However, these local government institutions though decentralised, still depend on central government for most decisions. Their programmes are almost fully government funded and more often, their budgets are cut by central government. They therefore do not have adequate funding for their activities. Financial capacity, technology and infrastructure were rated as inadequate by almost all the institutions contacted. According to them, all their activities cannot be undertaken if funds are not available. NADMO for instance, in their responses to the questionnaire, indicated that their operations are more or less ad hoc since they cannot predict exactly the nature, type, extent of damage, etc. of a hazard in a particular year. As such, they cannot budget adequately for them. They therefore assess the impact of the disaster after it had occurred and send a report to Accra before some money is released for relief activities. All these processes cause delays and more often the funding from government is inadequate. Most communities attested that NADMO comes around when there is a disaster but had different reasons for NADMO not attending to them when they are hit. Politics, corruption, and nepotism were the reasons given by the community level respondents for NADMO not responding adequately to their needs. Some NADMO officials conceded a minimal political influence at the level of Assembly Members, especially the powerful ones on the side of the government of the day.

Besides providing relief items to victims of disaster, NADMO also provide early warning. They do this in collaboration with the Ministry of Information through the use of the information services vans. These vans go round the villages to make announcements when they receive signals from GMet about any hazardous weather patterns and also from neighbouring Burkina Faso on the opening of dams. They also make radio and TV announcements. The early warnings were largely acknowledged by the respondents as being received chiefly through radio and information service vans. DADUs also provide extension services in relation to new technologies and also on the happenings of the weather, especially on drought, diseases and pests, through the agricultural extension agents who are supposed to be residing in the villages. Due to poor infrastructure in the villages the extension agents instead reside in the big towns and ride motorbikes to the villages. The ban on motorbikes in Bawku affected the operation of extension agents and some NGOs in the area. The NGOs provide additional services in the form of sensitisation and advocacy and fund some of the development projects. The NGOs on their part indicated that their area of operation is largely capacity building, advocacy, credit and relief assistance. Insufficient funding was their problem.

The private sector in the Region comprises of small scale businesses, artisanal activities and trading (Ghana Statistical Service, 2012b). Though some may be operating in the rural areas, the fieldwork found that more than 98% of these private sector institutions are located in the big towns or district capitals. Their reasons for locating in these towns were obvious; closeness to market and office and residential space. Due to the fact that the Region's economy is very small and also dependent on agriculture which is suffering from the weather, businesses are not able to grow and therefore unable to attract the necessary investments. The respondents from this sector who were either employees or owners of the businesses indicated lack credit and markets (i.e. low purchasing power of the people) as their key hurdle. The research also found that there are some commercial farmers in the Region but these people also face a similar fate. In an in-depth interview with a commercial farmer at Garu, he mentioned lack of credit, insurance, storage and processing facilities as his major problems. The problem of processing facilities is particularly marked in vegetable production because these crops are perishable. The only tomato processing plant in the Region is idling and rusting and the tomatoes produced rot, especially during bumper harvests. This has resulted in production losses for many farmers and was seen as a serious constraint by the participants in the group discussion in Navrongo. The participants in this group said they sometimes have to sell their produce at giveaway prices to the market women and therefore are unable to repay the loans taken to invest in the farms.

5.5 Synthesis

The adaptive capacities or livelihood activities discussed above do not operate in isolation. They relate to and influence each other. Increased agricultural productivity, for instance, will aid food security and reduce malnutrition. It will also increase incomes for households, thus enabling the people to pay for healthcare and build durable and hazard proof structures.

Increased access to health services will most likely reduce the health impacts of climatic hazards and help to build a healthy and productive population. The achievements of positive socio-economic conditions need an enabling environment which should be provided by institutions. The institutions work towards providing this enabling environment through extension services, outreach programmes, subsidies, increasing and enhance infrastructure, credit, agriculture inputs, among others.

To discharge their duties effectively, the institutions require adequate and timely release of funds and logistics. Delay or inadequate funding may increase the cost of certain projects and hence increase the cost of adaptation (Stringer *et al*., 2009). If these processes are too slow, they may result in maladaptation. Thus, the interactions between the livelihood activities may result in coping strategies that may enhance or reduce adaptive capacity (Dixon *et al*., 2014; Bermann *et al*., 2012). Thus, it is necessary to examine the various coping strategies of the people in the Region.

5.6 Coping strategies

There are other coping or adaptive strategies the people in the Region employ to minimise the impacts of hazards but these strategies cannot be captured directly under the livelihood framework. In coping with crop failure, the respondents indicated they most often reduce the number of times they eat, especially in the lean season to once or twice a day and also the quantity of food is reduced. The WFP (2012) reported similar practices in the three Northern Regions where the quantity of food consumed per day was reduced. This option has important negative impacts as it contributes to the high malnutrition in the area (Ghana Statistical Service *et al*., 2009) but it is becoming more or less an acceptable norm, especially among the poor rural households. Food aid has frequently been sent to the area in recent years by government and partner agencies to reduce the impact of food shortages resulting from crop failures.

On coping with the destruction of buildings by windstorms and heavy precipitation, some people are placing logs on the roof of the buildings to provide weight so that the wind cannot easily lift them up and rip them off while block material and roofing sheets increasingly being used as building and roofing materials (Fig. 5.9). Almost every house has at least one room with roofing sheets on it. These materials trap heat and keep it longer than the traditional materials. People sit outside under shady trees during the day, especially in dry season to avoid the impact of the heat trapped under the roofs and also they open their windows to allow air to enter the rooms.

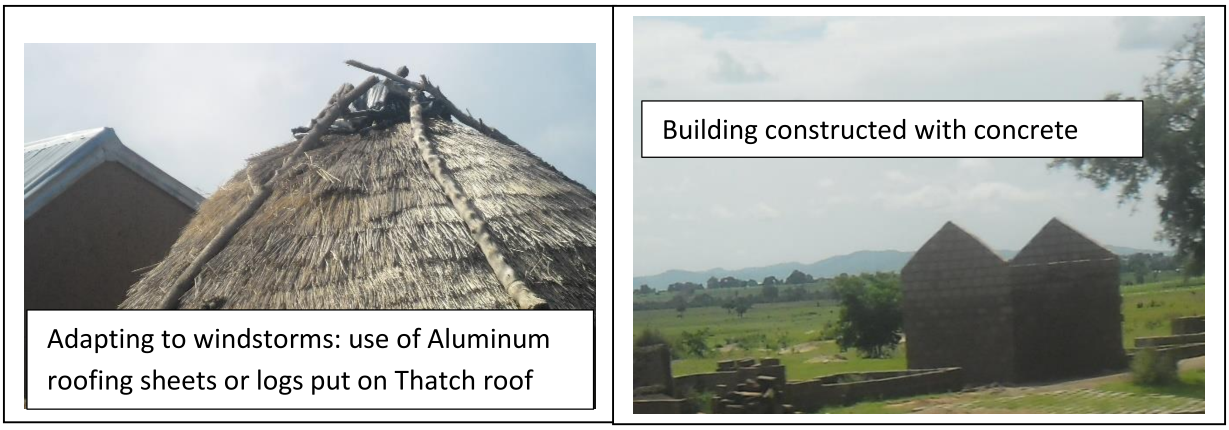


Fig. 5.9 Some strategies used to adapt to the hazards in the housing sector
Source (Taken by Author during field studies)

Those that have electricity mention the use of fans to increase air circulation in the rooms. Those with no electricity, the people especially those in rural areas, indicated that they have been advised through the health outreach programmes (on radio and at the health facilities) to sit in the shade outside the rooms during the hottest sunny time of the day. People plant trees (especially mango) close to their houses to provide shade as well as fruits for eating and selling, although the survival rate of the trees is very low. Those who are not successful in getting shady trees close to their houses use sorghum stalks to construct stalls to provide shade during the day. To deal with the increasing soil fertility loss and erosion, they use animal dropping and stone bunds (Fig. 5.10A). The animal manure ranges from fowl droppings to cow dung (Fig. 5.10B) and some of them avoid burning and allow the farm remains to rot on the farm.

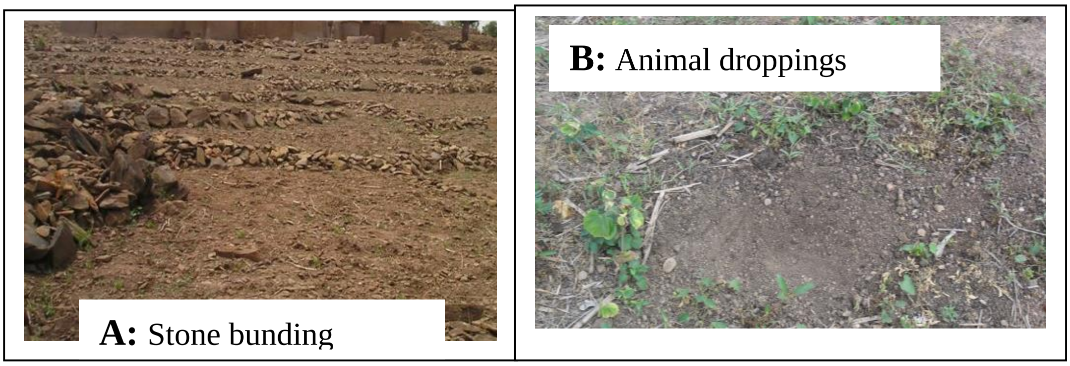


Fig. 5.10 Stone bunds and animal droppings on farm
Source (Taken by Author during field studies)

These droppings and farm remains according to them maintain soil moisture longer and help the crops to survive long dry spells. Some studies also found similar practices (e.g., Callo-Concha *et al*., 2012; Seefeldt, 2013).

5.7 Summary

The objective of this chapter was to identify the adaptive capacity available to the residents of the Region in dealing with climatic hazards. This was done using the livelihood assets dynamic structures and process as well as coping capacities captured under the framework as indicated in Fig. 5.1. It is clear that the people employ a lot of options in order to make good use of the environment for a living but these strategies are not good enough to make them overcome the impacts of the hazards. These include the use of the land as a natural base, application of fertilisers, construction of dams/dugouts for irrigation and livestock use, alternative livelihood activities such as mining, quarrying, formal employment, skills, etc. Others are remittances, social networks, the use of durable building materials, reduced activities during the day, reduced food intake, as well as planting of edible trees. These activities were aided by government institutions and NGOs operating in the areas. However, adaptive capacities are weak as they are able to squarely deal with the impacts of the hazards particularly food shortage, destruction of property, etc. leading to constant calls for aid from government and donor agencies. With these low capacities and the high level of exposure and sensitivities, it is necessary to overlay these together to determine the extent of vulnerability as well as delving deeper into the spatial variations of vulnerability in the Region.

Chapter 6 Development of indicators of vulnerability

6.1 Introduction

Objective 3 of the study was to map vulnerability, defined as a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. Mathematically,

$$Vulnerability = f\,(exposure, sensitivity, adaptive\ capacity) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6.1$$

Kienberger *et al*. (2009) argued that this definition is difficult to implement practically, especially in data poor countries because it includes all elements of both bio-physical and socio-economic factors which are difficult to realise locally. They further pointed out that the hazard term in the equation (i.e. exposure) serves to scale the variability of vulnerability spatially and temporally, and therefore suggested that for any particular place, time and hazard, vulnerability = f_H (sensitivity, adaptive capacity) where H represents the hazard. Using this conceptualisation and drawing on the relevant part of the framework (unshaded) in Fig. 6.1, susceptibility becomes synonymous with sensitivity for a particular hazard at a given place and time. However, it must be noted that elements have to be exposed to the hazard in order to show sensitivity to it. Thus, susceptibility in this research becomes the combination of the spatial component of exposure and sensitivity.

This reduces equation (1) to

$$Vulnerability = f_H\,(susceptibility, adaptive\ capacity) \quad \ldots\ldots\ldots\ldots\ldots \quad 6.2$$

The operationalisation of the definition of vulnerability this way makes it possible to spatially map it at a specific point in time. Mapping vulnerability will pictorially show hotspots of vulnerability and aid to target interventions to reduce such vulnerabilities at those locations. This is because the indicators used for mapping co-occur spatially and therefore aggregating them will portray the spatial patterns of relative vulnerabilities (Abson *et al.*, 2012).

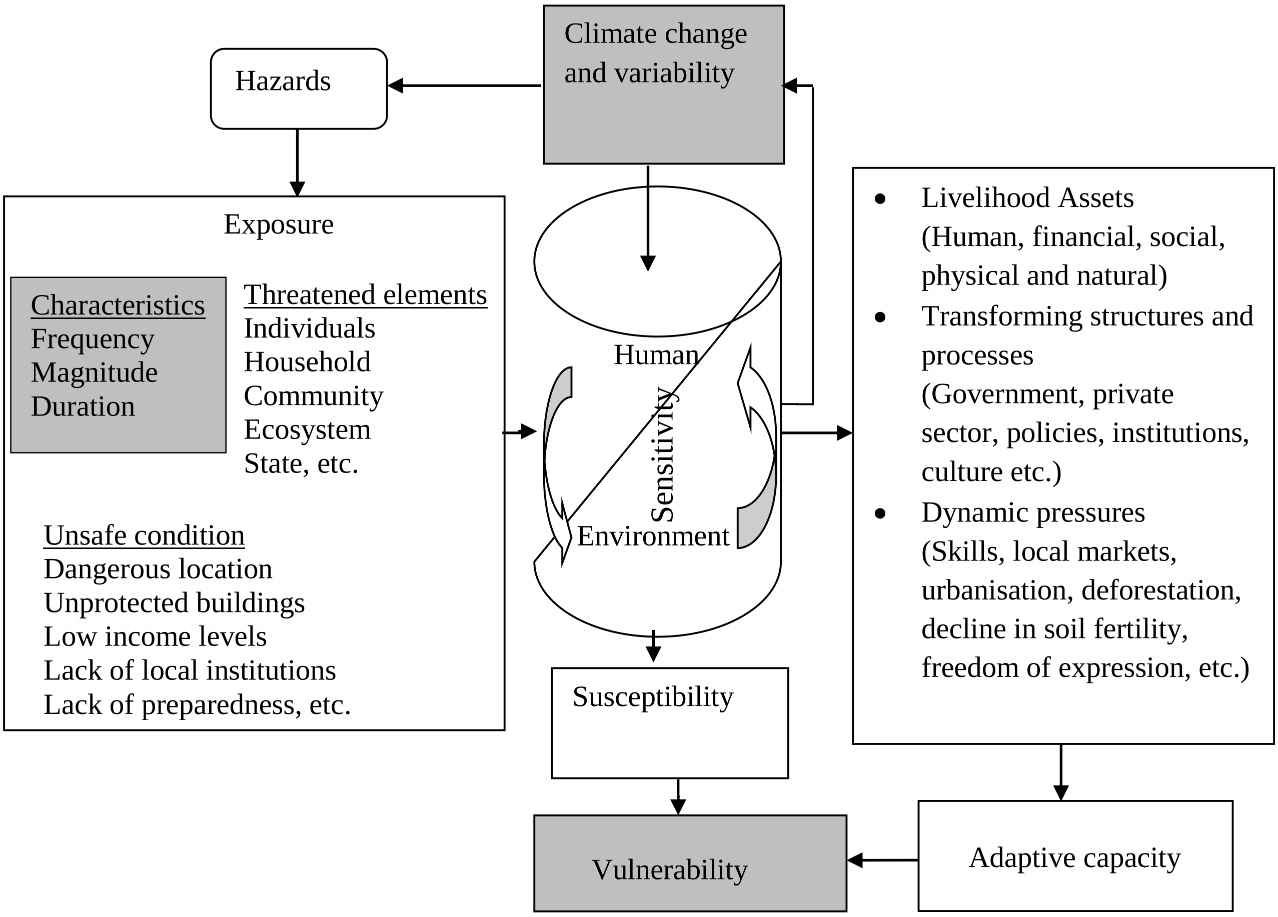


Fig. 6.1 Susceptibility and adaptive capacity indicators[20]
Source (Author's own construct)

Before vulnerability can be mapped, the data necessary to do the mapping has to be converted into geographic layers. This chapter aims to bring together the bio-physical and socio-economic factors identified in chapters 4 and 5, as susceptibility or adaptive capacity indicators and converts them into geographic layers for mapping in a GIS. This is a quantitatively driven step and requires quantitative data to accomplish. The data was obtained largely from secondary sources to quantify the indicators, but complemented with

[20]unshaded parts are tackled in this chapter

data from the field survey, especially in cases where data was not available. In this research, an indicator is conceptualised as follows:

- An indicator is a variable which is an operational representation of a characteristic or quality of a system able to provide information regarding the susceptibility, coping capacity and resilience of a system to an impact of an, albeit, ill-defined event linked with a hazard of natural origin. The relevance of the indicator for estimating a certain quality or characteristic of a system arises from the interpretation made about the indicator and its relationship to the phenomena of interest (Birkmann, 2006:57).
- The indicators are built into composite for the mapping purpose. In this case, a composite indicator is an indicator that maps (or aggregates) a vector of observable variables to one scalar theoretical variable. The Human Development Index (HDI; UNDP, 1990), for example, maps values of the four observable variables, namely life expectancy, adult literacy, mean years of schooling and income (O_1, O_2, . . ., O_n) to the theoretical variable human development (T) (cited in Hinkel, 2011:201).

The mapping involved converting the datasets into raster data layers since spatial analyst operations are best performed in raster format (see Damm, 2010). Note that in the rasterisation operation, the quantitative information or data obtained for each indicator was used in its raw form to create the raster before normalisation. This was so because normalisation before rasterisation would have resulted in continuous rasters which would not have permitted transformations and further normalisations. The chapter is divided into sections that discuss the development of susceptibility and adaptive capacity layers, normalisation and transformation, and weighting and aggregation. The evaluation of these processes is done in Chapter 7 after the mapping exercise.

6.2 Development of susceptibility layers

This section gathered all the indicators of exposure and sensitivity into geographic layers called susceptibility layers of the various sectors for each hazard. Various studies have used similar procedures to identify indicators and combined them this way (e.g. Kienberger *et al*., 2009; Damm, 2010). The indicators that were used and the relevant datasets for the quantification are described below.

6.2.1 Susceptibility indicator datasets

Following from equation 6.2, susceptibility measures the degree to which systems/livelihood activities are adversely affected by hazards. The different livelihood activities identified are susceptible to different hazards, as these are located at different places over space and take place at different times. Thus, to practically implement the concept of susceptibility described in section 6.1 requires the categorisation of livelihood activities into a series of components related to sectors of the economy, as proposed by Villagrán (2006, cited in Kienberger *et al.*, 2009), that are affected by the hazard in question.

From the analysis presented in chapter 4 and the literature, the more critical sectors identified to be susceptible to climate hazards in the Region include agriculture, health, housing, water and roads. The results from chapter 4 show that the occurrence and effects of droughts and high temperature as well as that of floods and high rainfall were difficult to separate by the people as these usually occur concurrently. So, these hazards were grouped as droughts/high temperature to and floods/high rainfall simplify the mapping process. Grouping also helped to reduce the effect of double counting (i.e. correlation effect) between indicators in forming composite indicators (Nardo *et al*., 2005). The sectors and indicators used are presented in Table 6.1. Considering that this is a data scarce area, all indicators with reliable datasets available at the time were included in the research. The datasets were in different formats and those without geographic coordinates had to be georeferenced (i.e. given geographic coordinates). Most of the datasets were at district level and were georeferenced using the district boundaries. The georeferenced indicators were grouped according to sectors as noted earlier. This means that susceptibility layers were first aggregated at sector level before determining the final susceptibility to each hazard. The advantage in this is that it allowed for within and between sector susceptibility comparisons to be made, thus identifying components and sectors that are most susceptible to the hazards.

Table 6.1 Indicators for susceptibility mapping

Drought/high temperature	
Sector	**Indicators**
Agriculture	Crop failure, pasture, water holding capacity
Health	Food security, population distribution, CSM, engaged in Agriculture
Water	Surface water, groundwater
Flood/high precipitation	
Health	Displacement, casualties, malaria, vulnerable group
Agriculture	Crop failure, soil loss, erosion
Housing	Number of buildings destroyed, proximity of properties to rivers, experience with flash flood, building materials used
Water	Not enough information and was left out
Roads	Nature of road, i.e. first class, second class, third class
Windstorm	
Housing	Roofing materials

Source (Based on field studies by Author)

6.2.2 Susceptibility to drought/high temperatures layers

The major livelihoods of the people that are affected by drought/high temperatures include livelihood activities such as crop production, livestock farming, human health and water availability. The agriculture sector is discussed below, alongside population and key biophysical aspects of the Region, to explain and identify the datasets necessary for mapping these sectors. The data used were determined by availability and validity. Validity simply refers to the appropriateness or soundness of using the data as an indicator (Damm, 2010) and is explained where a dataset is being considered for use as an indicator. The source of the dataset is also stated there.

6.2.2.1 Agriculture

The agriculture sector is susceptible to events of droughts/high temperatures. Droughts result in crop failure and death of animals due to scarcity of fodder and water. The crop failure index calculated in chapter 4 (section 4.2.3) was used to indicate the susceptibility of crops to hazards. The average crop failure index for 2011 was used as an indicator of crops susceptibility to drought. The index represents the sensitivity of crops to droughts/high temperatures. This index was obtained after removing the effects of technology and other factors by detrending as described in section 4.2.3 of chapter 4 and therefore any production loss could be attributed to climatic hazards (Simelton *et al.*, 2009). It was also computed from current crop data at district level. The indicator is therefore technically valid. Thus, crops and districts with higher crop failure indices were more susceptible to droughts than those with low values.

The effect of drought on livestock was determined using the area of grassland in the district. Grassland size was used as a proxy because when there is drought, the grass is not able to grow well and this affects pasture for animals. Animals are guided to open grasslands in the rainy season to graze and are left on free range in the dry season. The dataset was obtained from a Landsat classification by the Centre for Remote Sensing and Geographic Information Services (CERSGIS) in 2010. The dataset was clipped with the district boundaries to determine the grassland size per district. It is therefore valid for use as an indicator. Districts with large tracts of grassland were assumed to be better off in drought years than those with smaller areas because the animals can roam more widely to find fodder. It was assumed that the cultivated areas are considered unavailable to animals for grazing. Therefore the area of grassland in each district was used to map this indicator. In the dataset, open and closed savannah woodlands were considered as pasture lands since they are also being grazed by animals and were combined with the grassland.

The reduction in water holding capacity (WHC) was derived from a study by Amegashie (2009) where he sampled some areas in the Region to determine catchment erosion, sedimentation and nutrient export of small reservoirs. The study sites of Amegashie were plotted on the soil map obtained from GIS database of Ghana to determine the reduction in WHC for soils in the Region. Thus soils where the points fell were given the WHC values he derived. This process was preferred to interpolation since interpolation would have produced a continuous grid (Sluiter, 2009) which cannot be normalised and/or transformed. Therefore, soils with similar properties to the soils where the points fell were assigned the same reduction in water holding capacities as the points. Sampling was done in 2009 and was done at different locations within the catchment of each reservoir using modern equipment and scientific methods of data collection and analysis. Therefore the data was technically valid for use as an indicator. The reduction in WHC he obtained were used to indicate the susceptibility of the soils and agricultural sector to drought. Soils with high reduction in WHC were considered more susceptible to drought than those with low WHC. This is because these soils have their WHC reduced greatly and with the high and increasing temperatures, these soils will lose the water and greatly affect crops in those areas more than those with less reduction. The maps for the agricultural sector susceptibility are shown in Fig. 6.2.

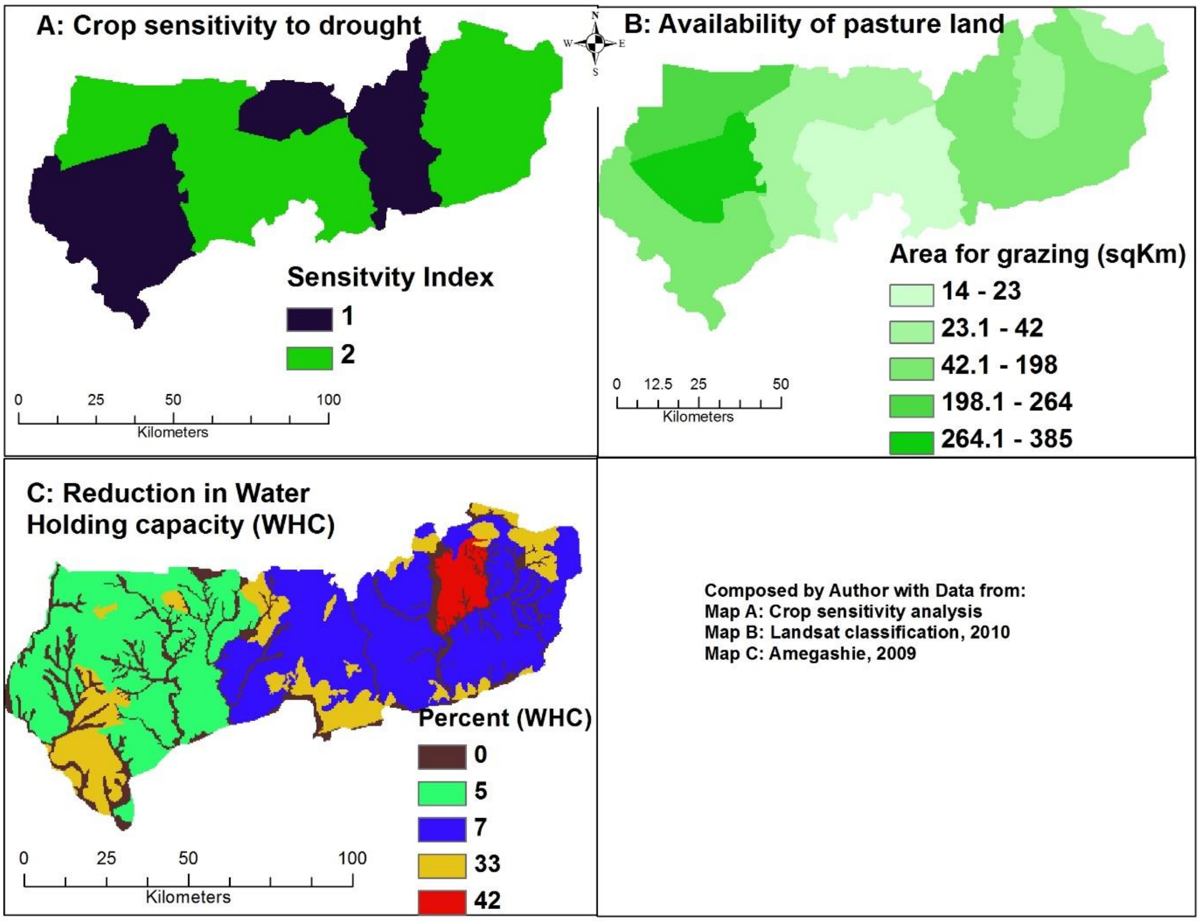


Fig. 6.2 Susceptibility of agriculture to drought/high temperatures

From Fig. 6.2, the crop sensitivity index was high in only three district, Bawku West and the Builsa North and South Districts. For availability of pasture land, the Builsa North District had more land and was assumed less susceptible to drought than the other districts with Talensi, Bolgatanga and Nabdam being more prone. The Binduri District had higher reduction in water holding capacity while the Kassena-Nankana and Builsa Districts have the least. The riverine soils (i.e. soils on the riverbed) were assigned zero because they were considered not available for agricultural activity.

6.2.2.2 Health

Drought/high temperature affects the population in several ways but most importantly, they can lead to food shortages and bring about illnesses such as Cerebrospinal meningitis (CSM) and malnutrition as well as a reduction in income. The food shortage component was determined using the food insecurity status of the districts obtained from the World Food Programme (WFP, 2012) report. The dataset also served as a proxy for malnutrition since it was difficult to obtain data on malnutrition. This dataset was linked to the district shapefiles in ArcGIS 9.3 and used to map the food insecurity indicator. Food insecurity indirectly indicates the effects of droughts/high temperatures on crops, particularly because most of the people in the Region, especially the rural poor, depend largely on food produced locally for household consumption (WFP, 2012). When there is a food shortage, prices of food stuffs increase astronomically in the Region. This makes those people in the two lower wealth quintiles especially, resort to unacceptable coping strategies, such as going hungry for days (WFP, 2012).

From the field survey presented in chapter 5, respondents indicated that they reduce food intake during the lean season (both in quantity and number of meals per day) as a coping strategy. This eating habit results in malnutrition, particularly among children and women, and could explain the high malnutrition levels in the Region (Ghana Statistical Service *et* *al*., 2009). Thus, food insecurity was considered as a proxy for measuring the effects of droughts on the population (i.e. malnutrition). The validity of this is that districts with higher food insecurity are likely to have higher malnutrition levels than the food secure districts.

Drought affects the entire population but the impact is more on the rural population, therefore, the distribution of the population was mapped according to whether the area was urban or rural. This data was obtained from the 2010 population and housing census. It was assumed that districts with higher rural population will be more susceptible to food crisis due to droughts than those lower numbers of rural population. This layer containing the population information was used to map the population distribution indicator. Another indicator used was the number of households engaged in agriculture. Households engaged in agriculture were considered more susceptible to droughts than those not involved in agriculture since they suffered from reduced income whenever drought occurred. Thus, the number of households involved in agriculture in each district was considered in mapping the susceptibility to drought. This data was also obtained from the census report. Districts with a higher number of households in agriculture were considered more susceptible than those with lower households.

CSM case fatality rates for the various districts were used to map the CSM indicator. This data was obtained from the regional health report (Ghana Health Service, 2012). Generally, data showed an increasing incidence of CSM cases between 2006 and 2012 which corresponds to the increasing trend of temperature in the Region as indicated in chapter 4. The fatality rates were chosen because it showed the degree of susceptibility of the districts to CSM in terms of lives lost per reported case. Therefore, districts with higher case facilities were considered more susceptible to high temperatures (i.e. heat). These indicator layers are shown in Fig. 6.3. From Fig. 6.3, districts of the former Bawku East (Binduri, Bawku Municipal, Pusiga and Garu-Tempane) are most populous while Kassena-Nankana West is the least populous. It also shows that there were more households in Bawku Municipal and Bolgatanga Municipal engaged in agriculture than the other districts. Districts with the least number of households engaged in agriculture are Kassena-Nankana West, Bongo and Bawku West. On CSM fatalities, Bawku West performed better than all districts and worst was Bongo with more case fatalities. Bawku municipal was more food secure than the rest with the Builsa Districts and Talensi and Nabdam Districts being more food insecure.

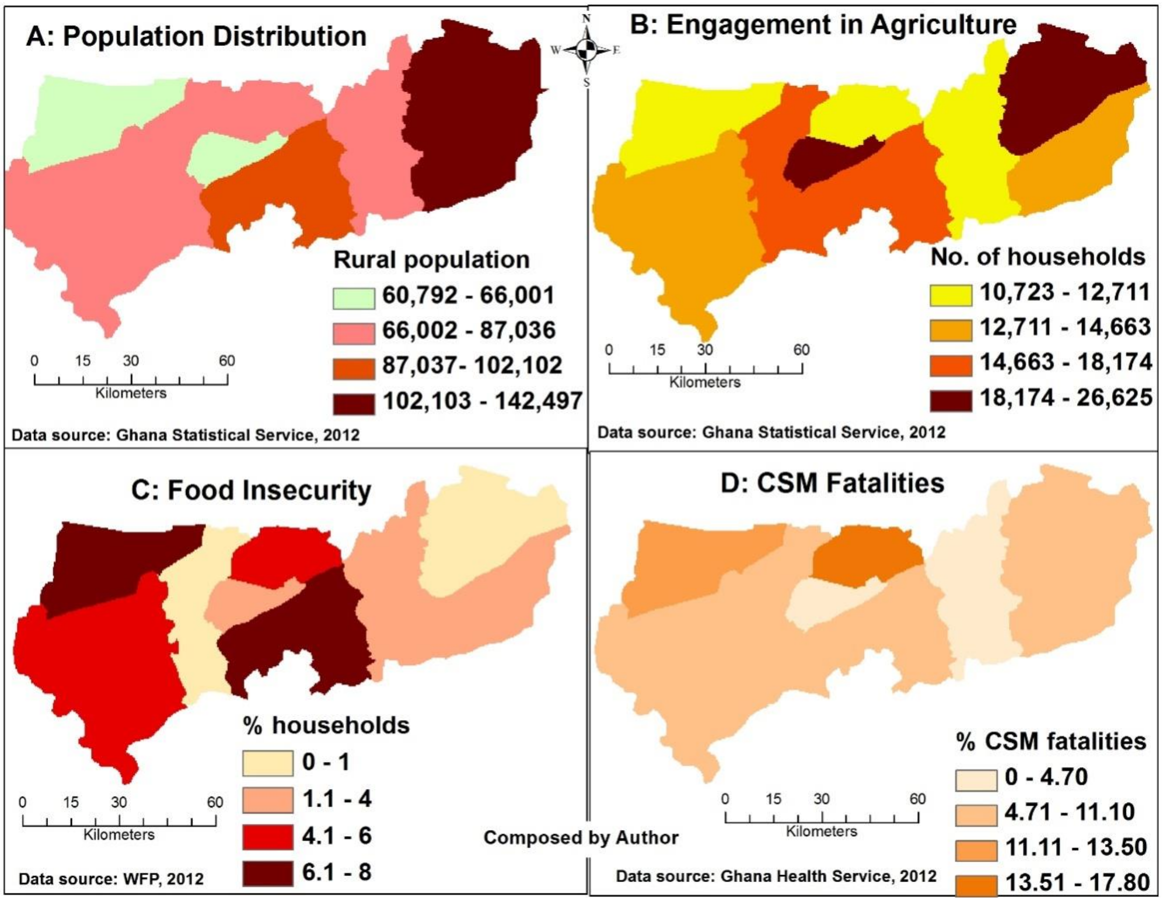


Fig. 6.3 Susceptibility of humans to drought/high temperatures

6.2.2.3 Water sector

When there is drought or high temperatures, surface water bodies dry up while ground water recharge reduces. For surface water, the number of reservoirs per district was counted and used to map the susceptibility of the district to droughts/high temperatures. The assumption here is that a district with a higher number of reservoirs will be less susceptible than one with lower number because it may still have some reservoirs with water and less crowding of animals and humans at the remaining few water points. A similar approach was used by Kienberger *et al*. (2009) where they took the number of spring water bodies to indicate the susceptibility of the district to floods. Data used in the present study was obtained from the GIDA (2013) in Excel format. Numbers were cross-checked with the dams identified on Google Earth and linked to the district boundaries since boundaries have been re-demarcated. Groundwater susceptibility was mapped using the recharge map produced by Obuobie (2008). This map showed the ranges of ground water recharges interpolated over the Region. The map was exported as a .jpeg file, georeferenced and digitised. The relevance of this indicator is that places with low recharge were more susceptible to droughts/high temperatures than those with high recharge rates. This is because the Region depends on groundwater for nearly all its domestic water requirements and some dry season gardening. Thus, those places with low recharge can easily run out of water for domestic and agriculture use. These susceptibility layers are shown in Fig. 6.4.

From Fig.6.4, the area with the highest recharge rate is in the Talensi District. This means that this area can rely on groundwater for a longer period than the other places and will be more resilient in terms of groundwater use. Conversely, some places in the Talensi district around Pwalugu and in Bawku West district around Zongo Yiri, have low recharge rates, and may suffer a water crisis during droughts. It must be mentioned that in the findings of questionnaire survey presented in chapter 5, residents of Pwalugu complained bitterly about water shortages always being problematic in the dry season, thus supporting this finding. Kassena-Nanakana East also has a lot of reservoirs and may likely suffer less in terms of surface water when there is drought. Talensi-Nabdam, Builsa South, Binduri and Pusiga have fewer reservoirs and are presumed to suffer more in terms of surface water when there is drought because these districts can easily lose their surface water bodies due to over-extraction of the few water bodies available. However, as a partial response to this problem, boreholes and mechanised wells in Region have been fitted with small concrete reservoirs to contain waste water for the animals.

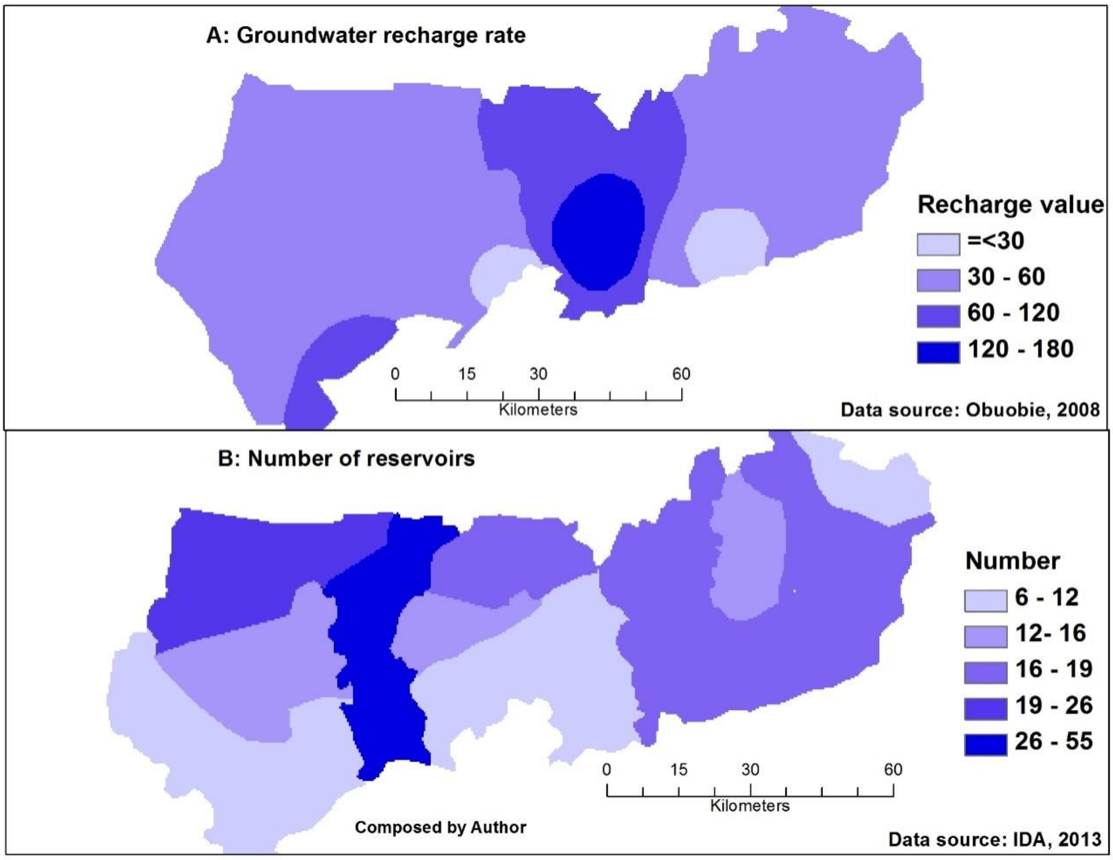


Fig. 6.4 Susceptibility of water sector to drought/high temperatures

6.2.3 Susceptibility to floods/high precipitation layers

Floods and/or high rainfall impact heavily on the livelihood activities of the people in the Region. The impacts range from crop failure, erosion of soil through to health problems and siltation of water bodies. The datasets required to map the susceptibility layers are described according to the main livelihoods, based on data availability and validity.

6.2.3.1 Agriculture

The average crop failure index of 2010 determined in chapter 4 was used to map the crop susceptibility to floods/heavy rainfall. This indicator was used because it is the net effect of the destruction of farms by floods and the frequent heavy rains that may prevent proper pollination of crops (Derbile and Kasei, 2012). Agriculture also suffers from flooding as the soil is eroded. Thus, the erosion component was determined from a proxy. Halm and Asiamah (1984) surveyed and mapped the types of erosion occurring in the Region based on the characteristics and properties of the soils. This map was digitised and used as a proxy. The reasoning is that erosion is determined by the properties and exposure of the soil, the land cover type and slope. These factors were considered by Halm and Asiamah (1984) in their survey. The erosion map (Fig. 6.5C) showed areas that were affected by normal erosion, areas affected by moderate sheet erosion, severe sheet and gully erosion and those affected by very severe erosion. These were rated 1, 2, 3 and 4 respectively using the categorical scale method (see Nardo *et al*., 2005).

Erosion also leads to nutrient and soil losses. Amegashie (2009) sampled soils in the Region and determined soil and nutrient losses due to erosion. The sites where he sampled were again plotted on the soil map and used to approximate the soil and nutrient losses for various types of soils in the area. This was done based on earlier assumptions made when considering the WHC in the section of susceptibility of agriculture to drought/high temperatures. The soil loss he determined were assigned to the various types of soils. Sampling was done in 2009 and was done at different locations within the catchment of each reservoir using modern equipment and scientific methods of data collection and analysis. Therefore, the data was technically valid for use as an indicator. These datasets were combined to map the soil loss indicator. The maps are shown in Fig. 6.5.For crop sensitivity, the Builsa Districts were more susceptible while the Talensi, Nabdam and Bolgatanga Municipality were less susceptible.

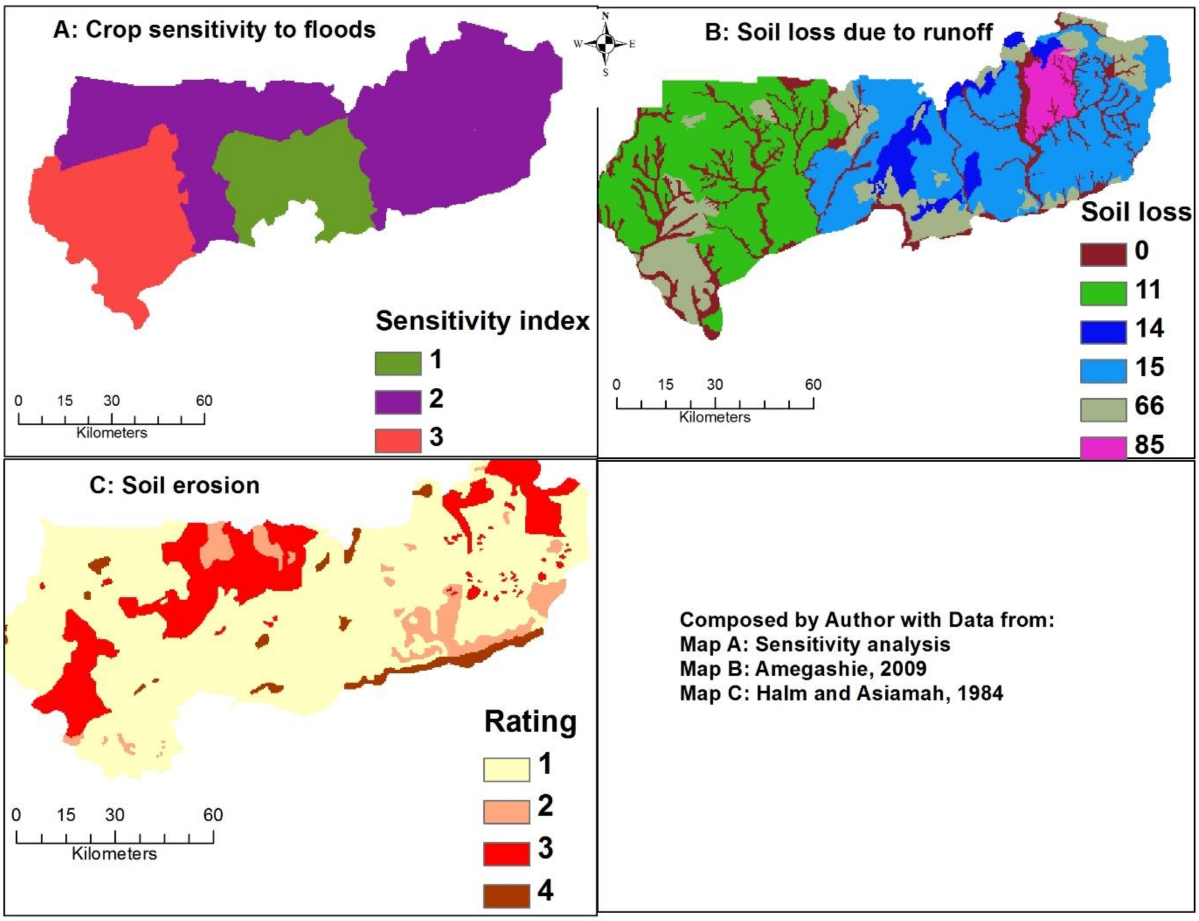


Fig. 6.5 Susceptibility of agriculture to flooding

As shown in the soil erosion and soil loss maps, the Builsa Districts have a large area with high erosion and high soil losses. This means that there is high runoff in these areas and therefore crops are washed away resulting in high crop sensitivity to floods/heavy rains. The soil erosion and loss varied across the Region. The riverine soils (soils of riverbed) were again given a score of zero because the soils are considered unavailable for agriculture use.

6.2.3.2 Health

Floods/high amounts of rainfall affect housing units and personal properties and displace people. The number of people displaced in each district was obtained from the regional NADMO office and used to map the displacement indicator. This data was collected after the 2010 flood event that was worsened by the opening of the Bagre dam in Burkina Faso. Thus, districts with more displaced people were considered more susceptible to floods than those with fewer displaced people. The number of casualties (i.e. injured and dead) was also used to create a casualties indicator. The casualty data was also obtained from NADMO. Districts with higher casualties were considered more susceptible to floods than those with lower numbers. As stated earlier in the introduction, floods/heavy rainfall leave behind pools of water that breed mosquitoes, the vector for transmission of malaria. Thus, the districts' susceptibility to malaria was determined from the health burden due to malaria using the percentage of Out-Patient Department's (OPD) attendance, admissions and fatalities in the health facilities at the district level. Districts with high rates are more susceptible to malaria and therefore, floods/high rainfall as transmissions are generally higher in the rainy season (Ghana Health Service, 2012). When there is a flood, people in the vulnerable group suffer more because they cannot help themselves. The people in this category comprised the elderly (i.e. 85+), children below 10 years and people living with a disability. The information on these categories of people were obtained from the census data and used.

Districts with higher numbers of these groups were more susceptible to floods than those with lower numbers. These maps are shown in Fig. 6.6.

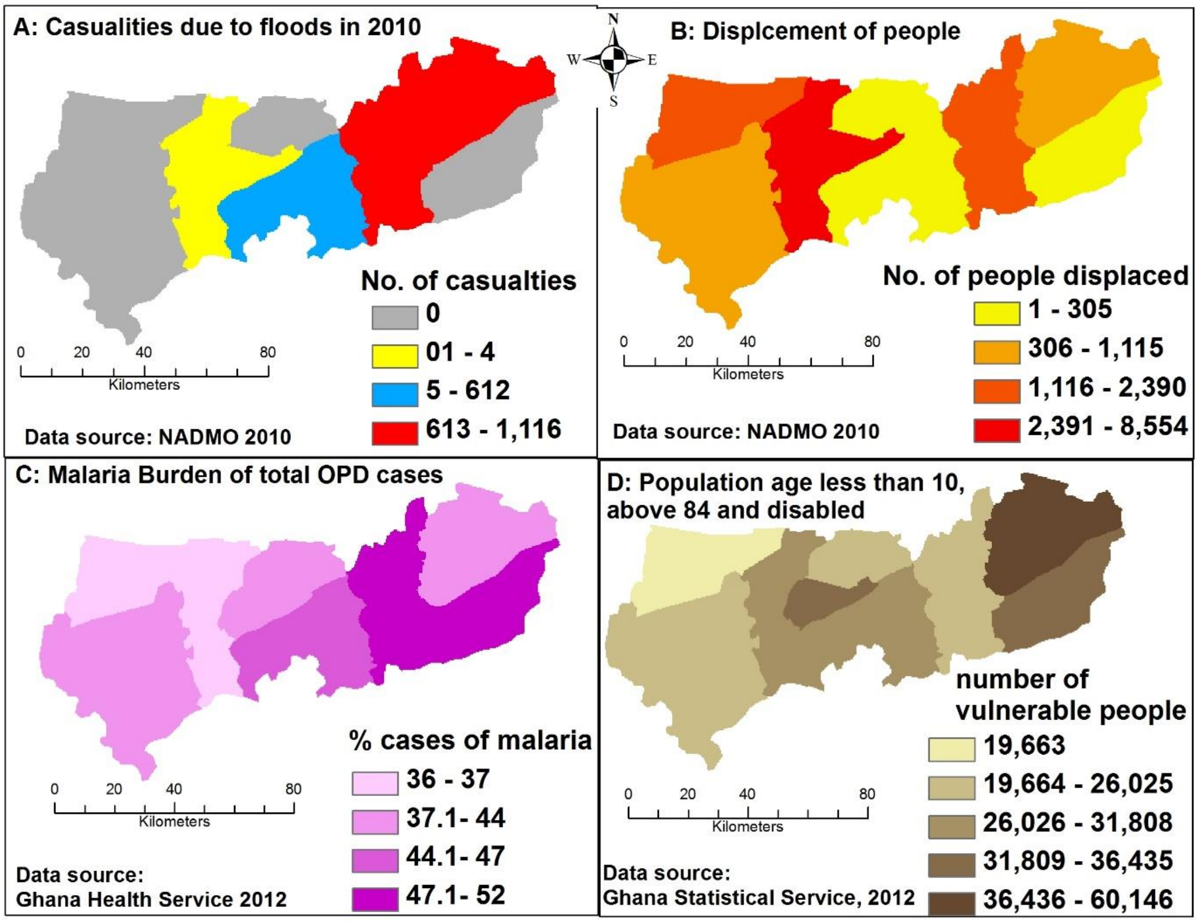


Fig. 6.6 Susceptibility of humans to floods/high precipitation

In 2010 as shown in Fig. 6.6, the flooding affected the districts sharing their borders with the White Volta; Bawku West and the former Bawku East which had high casualty rates. These districts suffer a lot from flooding due to their proximity to the Bagre dam. If the early warning information does not get to the villages along this river early enough, then high numbers of casualties are recorded. The NADMO data show similar high rates in the 2007 floods. In the questionnaire survey, some of the people at Kubore in Bawku West District and Kumpalgoga in Binduri District said they retrieved bodies of their relatives from the Gonja land closed to where the White Volta enters the Volta Lake. However, more people were displaced in the Kassena-Nankana East District and Bolgatanga Municipality than any other district. This could be partly explained by the presence of flash flooding as well as settlements closed to rivers/streams in the towns in these districts. For malaria, Bawku West and Garu-Tempane Districts suffered. Bawku Municipality had the highest number of people in the vulnerable category, followed by Bolgatanga with Kassena-Nankana West having the least.

6.2.3.3 Housing

Floods/heavy rainfall affects houses and personal belongings. The number of housing units that were affected in the 2010 floods was obtained from the regional NADMO office. These consisted of houses that were partially or wholly destroyed by floods/heavy rains. Districts with higher numbers were considered more susceptible than those with lower values. These were used to map the susceptibility of the housing units to floods/heavy rainfall. The location of the housing units in terms of whether they are close to a water body especially rivers/streams also exposes them to floods. The closer the buildings are to these water bodies, the more susceptible they are to flooding. Buffers were created from the rivers/streams with distances 500 m, 1000 m and above 1000 m. Those within 500 m were considered very close and assigned a value of 10, 500 to 1000 m were near and assigned a value of 5 while beyond 1000 m were considered far and assigned a value of 0. The assignment of these values were based on the categorical scale method (see Nardo *et al.*, 2005). A similar rating scheme was used by EPA (2012).

Flash flooding in the Region occurred largely in urban areas and therefore almost all urban towns (see Table 6.2) were visited to interview some people and to observe the drainage systems and their contribution to flooding. The questionnaire survey was also carried out in some of the urban centres which are the district capitals and affirmed the belief that flash flooding only occurs in urban towns. To rate the places, the district NADMO officials were asked about flash flooding history of their urban towns and also 3 additional respondents who stayed in certain localities in the towns were randomly selected and asked informally if they see floods in the vicinity and if they can tell its frequency and impacts. These findings were combined to rank the places as shown in Table 6.2. The categorical scale was used to assign these scores.

Table 6.2 Ranking of localities of flash flooding

Towns/locality	Score
Rural	0
Bolgatanga	5
Bawku/Navrongo/Zebilla/Paga	3
Sandema/Bongo/Garu	1
Tongo/Fumbisi	0

Source (Based on field studies by Author)

The quality of housing in the Region also makes the area susceptible to flooding/heavy rainfall. To map this, the percentage of mud buildings in each locality (rural/urban) was determined from the type of building material used in the district. Information was obtained from the 2010 census report. This was used as an indicator because mud buildings easily collapse when they become very wet. The maps of the layers to be combined to produce the susceptibility to flooding of the housing sector are shown in Fig. 6.7. The floods destroyed more buildings in Bawku West District, Bolgatanga Municipality and Kassena-Nankana East District with less effect in Bongo, Garu-Tempane and Kassena-Nankana West Districts. The destruction of buildings could be attributed to proximity to rivers or urban flooding.

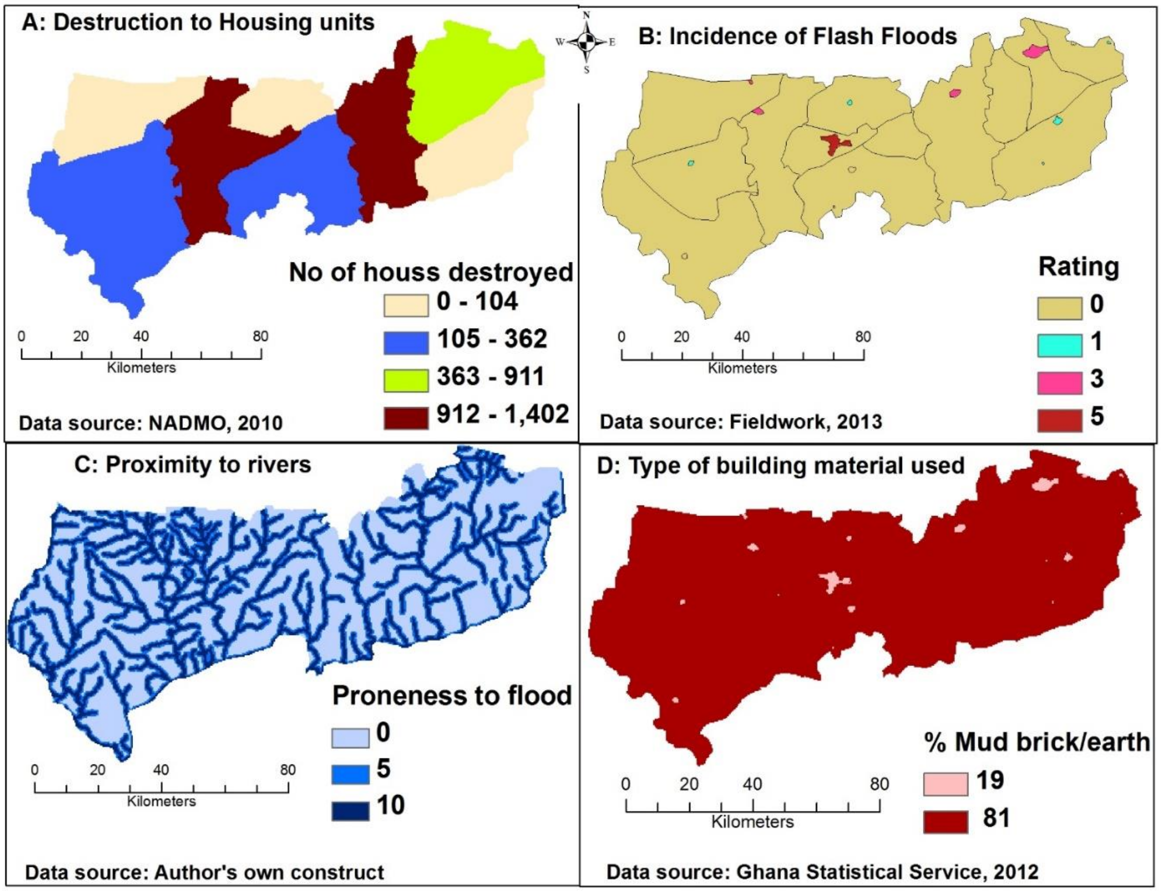


Fig. 6.7 Susceptibility of the housing sector to floods/high rainfall

6.2.3.4 Road sector

Floods/heavy rainfall sometimes cause damage to the road network. The damage could entail road being partially or wholly eroded, or bridges washed away, cutting off communities. When this happens, aid or access to those affected communities is also hampered. The susceptibility of this sector was mapped using the surface of the roads in the area based on the classification by the Ghana High Authority. These classes are defined as follows: first class represents bitumen surface roads and highways, second class represents feeder roads and third class represents tracks and footpaths. The lengths of these roads in the districts were used to map the susceptibility of the roads to floods/heavy rainfall. This is because the destruction of the roads varies by the nature of the road. Tracks and footpaths are more easily destroyed than feeder and tarred roads in that order. The dataset was obtained in GIS shapefile format and classified into these classes. The classification was cross checked on Google Earth to update the new roads. Though some of the tarred roads are currently in bad shape and worse than the feeder roads, it is believed that it would not affect the results significantly. As shown in Fig. 6.8, the roads in the Region are poorly developed and also in bad condition. There are more tracks and footpaths connecting villages and towns than secondary and first class roads. The tracks are most often muddy in the rainy season and it is difficult for vehicles to use them. It can be seen that only Kassena-Nankana Districts and Bolgatanga Municipality are doing better with roads. These have a relatively good road network.

6.2.4 Susceptibility to windstorms

Windstorms mainly affected roofs of buildings. Although it sometimes pulled some of the crops down, the crops are often able to rise again naturally or the farmers prop them up by supporting the base with soil. It was also gathered from the field survey that the effect of winds is more on thatch than roofing sheets and that windstorms had no effect on mud roofs. Thus, the percentage of thatch was used to map the susceptibility to windstorms. The percentage of buildings roofed with thatch was obtained from the 2010 census report. Districts with higher percentages of thatch were more susceptible to windstorm than those with lower values. The questionnaire respondents attributed the strength of windstorms to the reduction in tree cover which hitherto served as wind breaks.

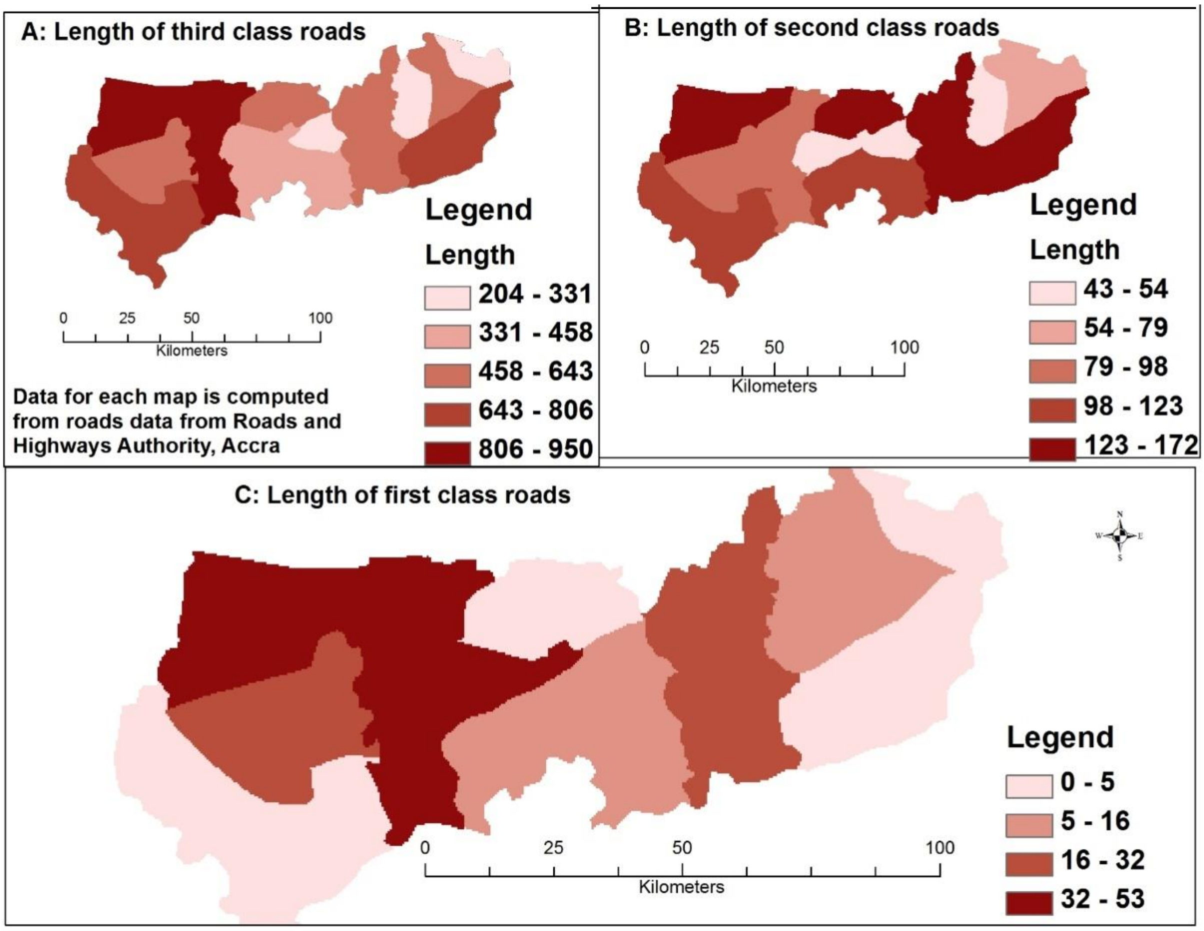


Fig. 6.8 Susceptibility of the road sector to floods/high precipitation

The savannah woodland cover was extracted from Aster 2010 satellite image classification and used as a proxy. The argument is that places with high tree density will have high tree cover to serve as wind breaks and therefore will be shielded from the effects of windstorms. Therefore, the land cover data was reclassified based on tree density as proposed by CERSGIS and used in producing the maps. Based on the discussions with the community members and observation of disparate measures in the villages as well as literature, the ratings in Table 6.3 were assigned to each land cover using the categorical scale. Places with lower tree density were considered more susceptible to windstorms and were assigned higher scores. The maps for the windstorms are shown in Fig. 6.9. From the figure, it can be seen that the urban areas are less susceptible to windstorms due to the high usage of metal sheets. The metal sheets are attached more securely than thatch roofs, which are fastened with jute. It is also realised that the areas to the eastern part, central and some parts in west of the Region have less tree cover and are more susceptible. Unfortunately, from the community members' accounts, the winds come from the east and are stronger as they sweep across vast areas of unprotected land.

Table 6.3 Rating of land cover types for windstorm susceptibility based on tree density

Land cover	Rating
Grass/herb with/without scattered trees (0-5 trees/ha)	50
Widely open cultivated savanna woodland (6-10 trees/ha)	40
Open cultivated savanna woodland (11-20 trees/ha)	30
Open forest (<60 %)	10
Closed savanna woodland (>25 trees/ha)	20
Reservoir	50
Riverine savanna vegetation	10

Source (Based on field studies by Author)

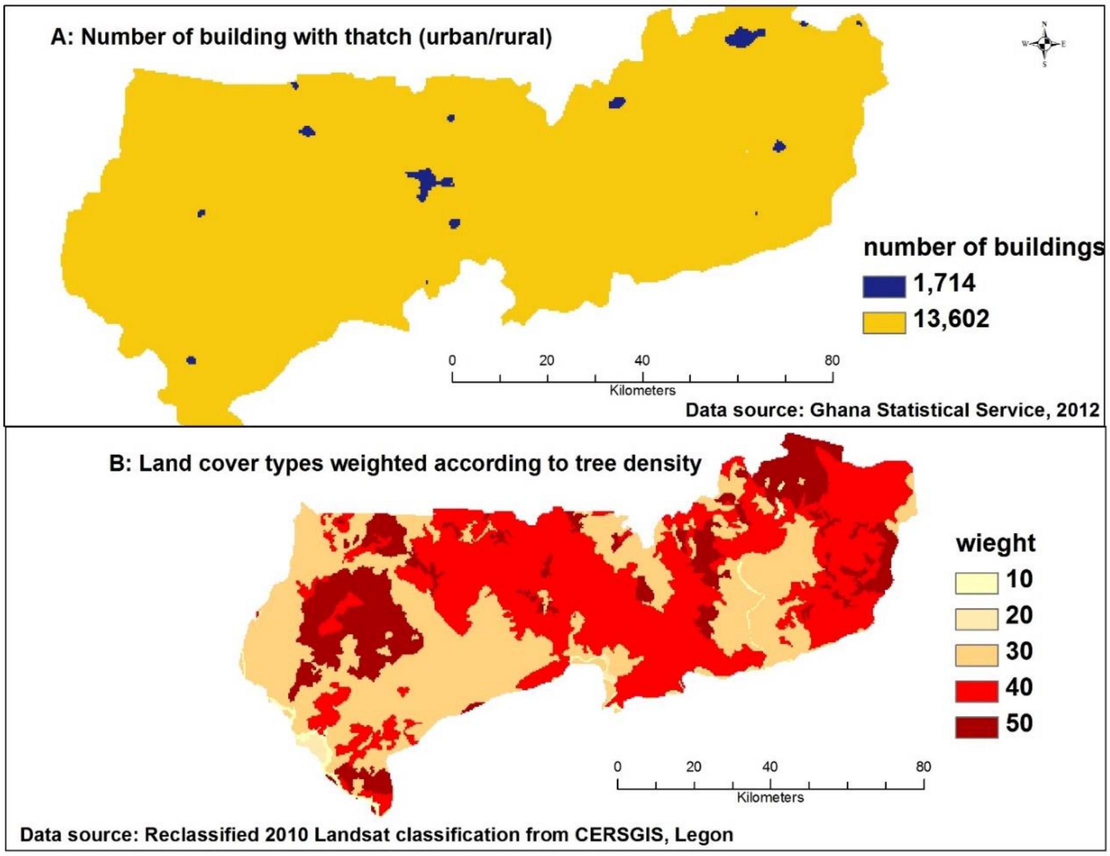


Fig. 6.9 Susceptibility to windstorms

6.3 Adaptive capacity indicator datasets

Following the arguments put forth in section 2.2.2.3 of chapter 2, adaptive capacity here encompasses social capacity and resilience as it reflects the social-ecological system's ability to take opportunities and to respond to threat posed by hazards. In this case, resilience is considered as the ability of the system to restore its status and functions to the state before it experienced perturbation, which includes consideration of its coping capacity (Kienberger *et al.*, 2009). Although other definitions of resilience exist (e.g. IPCC, 2014c), those that consider a system's capacity for transformation are not considered in the present study. Social capacity is considered to relate to society's activities that enhance adaptive capacity (Levina and Tirpak, 2006). Therefore,

$$\textit{Adaptive capacity} = \textit{social capacity} + \textit{Resilience} \quad \ldots\ldots\ldots\ldots\ldots\; 6.3$$

It must be mentioned here that this division is just to ensure that both social and ecological systems are covered as much as possible. This section is divided into social capacity and resilience to identify the proxies that could be used as indicators for adaptation to the hazards. Adaptive capacity was not divided according to hazard because when a hazard occurs, all capacities necessary to deal with the event are called to action. The reasoning here is that an indicator can be used to respond to any of the hazards should they occur. For example, wealth can enable a household to adapt to drought by buying more food, paying for electricity to cool their home or to adapt to floods by building high quality flood protection systems or by relocating more easily.

6.3.1 Social capacity

Social capacity covered human, financial and social capitals as well as the institutions that transform these into positive pressures and enhance the capacities of the people. This is in line with the social and institutional factors in the sustainable livelihoods framework (see Birkmann, 2006).

6.3.1.1 Human capital component

The human capital indicator was mapped using the level of skills and education of the people in the Region. The literacy rate for each district was used to create a layer for education. The rationale is that the more literate population a district has, the better its chances of having more people in other (non-agriculture based) forms of employment and hence a higher adaptive capacity. This data was obtained from the census 2010 report. The levels of skills of the district were assessed using the number of people employed in industries that are skill based. This was calculated from the 2010 census report indicating the number of economically active people in employment by Region and locality. Occupations that did not require skills or training and agriculture were excluded.

6.3.1.2 Social capital

In each district, there are a number of NGOs lending support to the people. The NGOs undertake a range of activities from advocacy to capacity building. Some of the NGOs provide these to organised groups and therefore encouraged people to form groups. These activities strengthen capacities to cope with the environment. The number of NGOs was obtained for each district from the institutional questionnaire, and supplemented with the list from the district profiles, and used as an indicator to map social capital. Thus, the higher the number of NGOs operating in a district, the better its social capital.

There are decentralised governments institutions in the Region in charge of managing some of these hazards, either directly or indirectly. The institutional capacities of institutions in the Region were assessed. These institutions rated themselves in terms of the financial, physical, technological and human capacities to deal with the hazards as part of their responses to the institutional questionnaire. Interviews with institutional heads or representatives sought to find out their rate of response when a hazard occurs. The response level of the institutions was assessed according to community members as indicated in chapter 5. This assessment resulted in a score of 10 and 3 for institutional capacity for urban and rural districts respectively using the categorical scale. These were used to identify the institutional capacity. The maps resulting from the data described above are shown in Fig. 6.10.

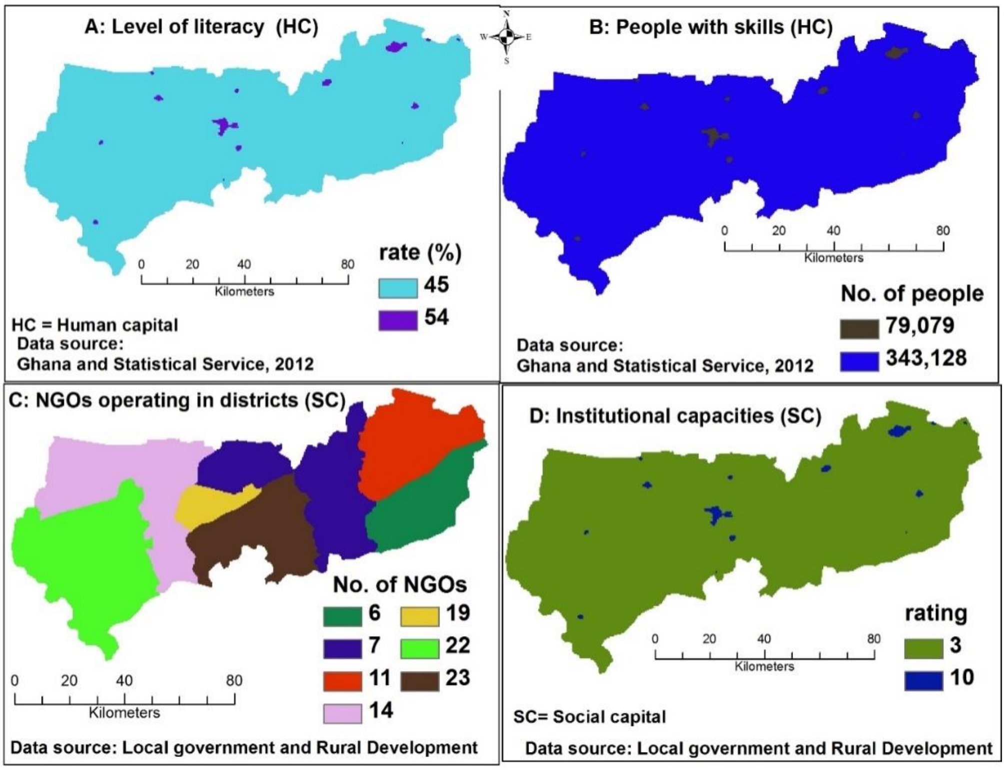


Fig. 6.10 Maps of Human and Social capitals

The urban areas had higher capacities in terms of literacy level and institutional capacities. However, the number of skilled people was more in the rural areas than in the urban area. These rural skills are largely craft works, weaving, pottery, etc. that pay less than the urban skills, which rely upon high levels of training or education.

6.3.1.3 Financial capital

Financial wealth, presence of financial institutions, and investment opportunities as well as employment status, were used to map this component. Financial wealth is a very good indicator of adaptive capacity as it shows the ability of the people to command resources to respond to hazards. The wealth of households in the districts was thus assessed using this index. The data for this was obtained from the WFP report and supplemented with the data from the census report to segregate into urban and rural households.

Financial institutions play a role in providing credit to support the victims of hazards. The financial institutions are the mainstream banks and micro-credit agencies or NGOs which source funds and give them to the community members in the form of credits for their livelihood activities. The number of financial institutions in a district was obtained from the district assembly's profile and used to map this indicator. Though some of these financial institutions operate within the urban areas, a few of the rural people who are able to meet the requirements of the banks get access to credit. The type of financial institution was considered in determining the rating for the district. For example, a national or commercial bank is put in a higher level than a rural bank, an NGO and a micro credit facility. Table 6.4 shows the ratings that were given. A district with the highest score was considered more financially sound than those with lower scores. It must be mentioned here that although some of the NGOs may be richer and do more than the rural banks, they are rated lower than the rural banks because banking is not their core business.

Table 6.4 Scores of financial institutions in the districts

	Type of institution								
	National bank		Rural bank		NGO[21]		Microcredit		Total
District	**No.**	**Rating**	**No.**	**Rating**	**No.**	**Rating**	**No.**	**Rating**	
Bawku Mun.	2	10	1	5	3	2	1	1	32
Bawku West	1	10	1	5	1	2	2	1	19
Binduri	0	10	1	5	3	2	1	1	12
Bolgatanga	7	10	3	5	3	2	2	1	93
Bongo	0	10	1	5	1	2	1	1	8
Builsa North	0	10	1	5	1	2	1	1	8
Builsa South	0	10	0	5	1	2	1	1	3
Garu-Temapne	0	10	1	5	3	2	1	1	12
KN East	1	10	1	5	2	2	1	1	20
KN West	0	10	1	5	2	2	1	1	10
Nabdam	0	10	0	5	4	2	2	1	10
Pusiga	0	10	1	5	3	2	1	1	12
Talensi	0	10	0	5	4	2	2	1	10

Source (Based on field studies by Author) KN= Kassena-Nankana

The investment opportunities in the districts also boost its capacity. In the district profile, the number of investment opportunities that are in operation were used to map this indicator. Thus a district with the highest number of investment opportunities is adjudged to have better opportunities and hence a higher adaptive capacity. Refer to Fig. 6.11 for maps. The Bolgatanga town seems to be wealthiest town while Bawku West and Pusiga Districts are the wealthiest districts. Bolgatanga Municipality also has the highest investment opportunities and highest number of institutions. This is because it is hosting the Regional capital and therefore has all the benefits associated with that.

[21] NGOs are those specifically providing financial assistance. The rating was arbitrary but based on financial capacity on the institutions

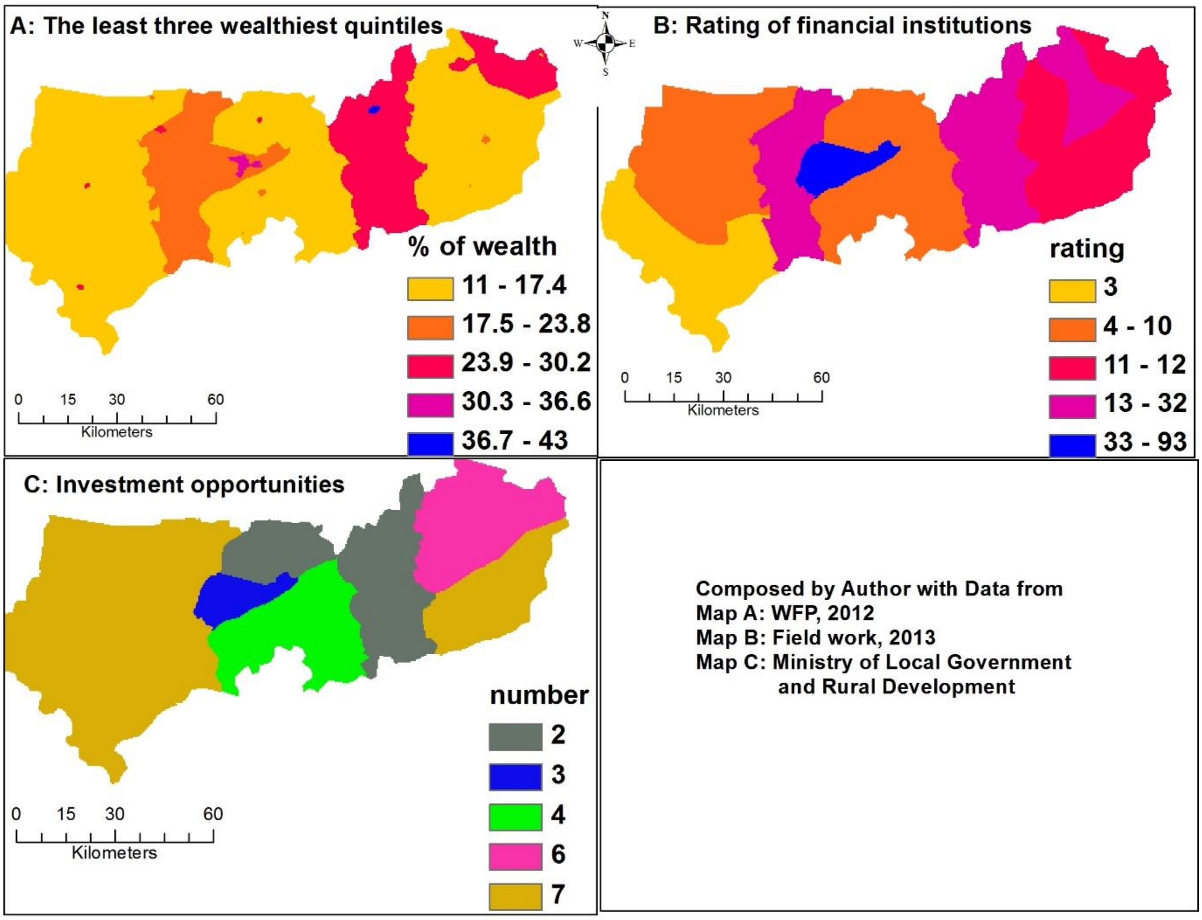


Fig. 6.11 Financial Capital

6.3.2 Resilience

In mapping resilience, the capacities relating the biological and physical assets were considered. That is, this subsection accounted for the natural and physical assets including the innate characteristics (or coping strategies) and the structures that help to support people to withstand the perturbations and disturbances.

6.3.2.1 Natural assets

The availability of the natural environment as well as its integrity is key for adapting to hazards. This is because the people depend on natural resources to eke a living. The natural assets component was mapped using indicators such as availability of land for human activities and protected areas. The size of each district was calculated and used to map the indicator for land availability. The rationale is that, the size of land available in a district determines its capacity to use that land to engage in a range of activities that will enhance its capacity to deal with hazards. Other natural assets such minerals are part of the investment opportunities under financial capital and are therefore not considered here. The dataset was obtained from the GIS database. Another ecosystem integrity indicator that was mapped was the presence of protected forest per district. This dataset was also obtained from the GIS database updated by CERGIS in 2000 and areas of reserves per district were calculated and used. The locations of the forest reserves in each district were extracted and mapped for this indicator.

6.3.2.2 Technology

This subsection covered the availability of technology and its use to better the livelihood activities of the people. Thus, it covered topics like the use of irrigation systems and early warning systems. As found in chapter 5, there is an early warning system in place. To map the capacity of the districts in terms of early warning systems, the effectiveness of the system was measured from the responses on how they use the information received from the early warning system. Those districts with low percentages represented those where a large number receive the information but do nothing with it because either it does not matter to them or they got the information late and therefore could do very little with it. The analysis also showed that the early warning information was always sent out when there is evidence of floods or windstorms but none for droughts. This was evident from the usefulness of the information: respondents moved their properties, harvested their crops or secured their roofs before these events occurred. The information for this indicator was generated from the questionnaire survey and institutional survey.

Irrigation dams/dugouts have been provided for dry season farming. To map this indicator as a capacity to adapt, the catchment area of the dams/dugouts was determined from the data obtained from Ghana Irrigation Development Authority (GIDA). The reasoning is that dams/dugouts with large catchment areas have the capacity to store more water for dry season farming than those with smaller catchments. The catchments of the two big dams (Tono and Vea) in the Region extend into Burkina Faso and some of their tributaries are dammed but the catchment area within Ghana was used. Maps for the natural capital and technology are shown in Fig. 6.12. Land availability is high in Bawku West and Builsa South Districts and low in Bolgatanga municipal and Nabdam District. It is also low in the urban areas due to urbanisation. Builsa South and Talensi Districts have high protected areas while Bawku municipal has the lowest. Kassena-Nankana East has more area under irrigation. This is expected because the largest irrigation scheme is located in this district and it has the highest number of reservoirs as well. It is also seen that use of information from the early warning system is high in the eastern part of the Region. As shown in the susceptibility maps, the eastern bloc of the Region seems to suffer more from floods and windstorms and therefore the information associated with these hazards help the people, especially those along the rivers a lot to move their properties or relocate before the floods come.

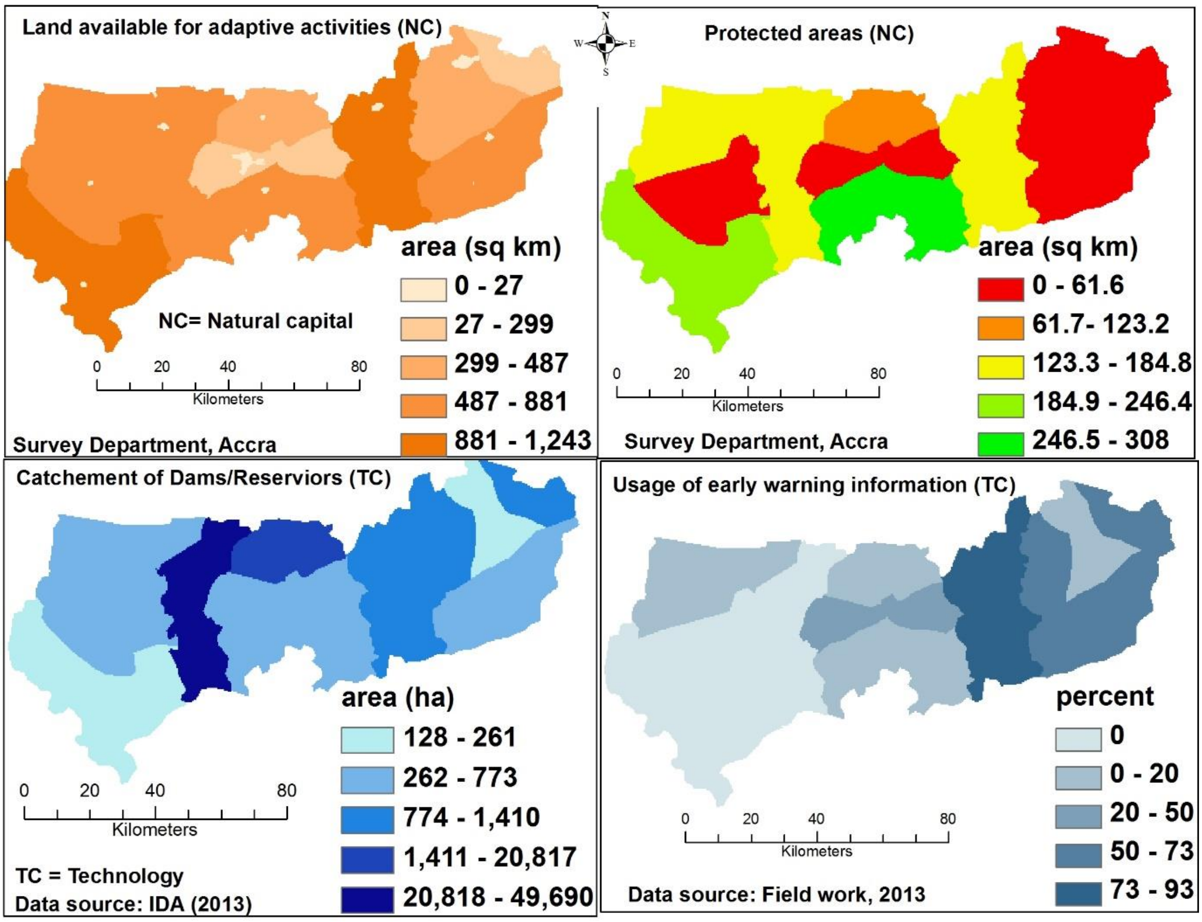


Fig. 6.12 Maps of Natural capital and Technology

6.3.2.3 Infrastructure

The indicators under this subsection relate to accessibility to services such as health, education, transport and the presence of markets. Health facilities were rated in the districts based on level of service, staffing, etc. For simplicity, all hospitals in the Region were put in the same category. The problem with the simplification is that some hospitals are better than others in terms of service, structures, staffing, infrastructure, etc. but it reduces the complexity of having to go into all these details in order to rate them. This has generally been used by the Regional or Districts Health Directorates when reporting the number of hospitals or classifying health facilities. Similarly, maternity homes were put in the same category as a Community-based Health Planning and Services (CHPS) compounds.

Maternity homes only offer care to maternal mothers. The ratings are shown in Table 6.5. It is assumed that districts with higher ratings have better infrastructure and a higher adaptive capacity health wise.

Table 6.5 Ratings of Markets based on functionality and structures

District	Hospital		H/C		Clinic		CHPS		Mat Home		Total	Market[22]	Rate
	N	R	N	R	N	R	N	R	N	R			
Bawku Municipal	2	200	6	50	9	30	16	5	1	5	1055	Bawku	50
Bawku West	1	200	4	50	10	30	14	5	0	5	770	Zebilla	30
Bolgatanga Municipal	2	200	7	50	7	30	14	5	0	5	1030	Bolgatanga	50
Bongo	1	200	5	50	1	30	27	5	0	5	665	Bongo	20
Builsa	1	200	6	50	0	30	21	5	0	5	605	Sandema	30
Garu Tempane	0	200	6	50	6	30	26	5	0	5	610	Garu	30
Kassena-Nankana E	1	200	2	50	3	30	18	5	0	5	480	Navrongo	50
Kassena-Nankana W	0	200	6	50	1	30	25	5	0	5	455	Chiana	30
Talensi Nabdam	0	200	3	50	5	30	16	5	0	5	380	Tongo	20

Source (Based on field studies by Author) N.B: N=number; R=rate assigned; W = West; E=East

Accessibility to health services is critical because it represents the districts' capacities to handle diseases and ailments and injuries relating to these hazards. The markets were however, rated based on the level of service, functions and structures. For educational infrastructure, the number of schools in each district was used. This was done because with the exception of basic schools which need to be closer to the pupils, the others are accessible to everybody. Therefore no ranking was done regarding educational infrastructure. Energy infrastructure was also used to map the adaptive capacity in relation to these hazards. This

[22] The new districts also had markets were rated as Ambrose (Binduri)=30, Fumbisi (Builsa South)=20, Pusiga = 30 and Pelungu (Nabdam)=30

is because energy is needed to power the cooling systems in the face of rising temperatures and to ensure some of the systems run efficiently. The energy infrastructure was measured by the level of coverage in each district. This data was obtained from the census report. It must be noted that close to about 96% of the energy from electricity is consumed by urban dwellers with about 4% consumed by the rural dwellers. Thus, this was used to map the energy infrastructure and maps are shown in Fig. 6.13.From Fig. 6.13, the Kassena-Nanakana districts Bolgatanga municipality have the highest amount of educational infrastructure while Bawku and Bolgatanga municipals have the highest in terms of health infrastructure.

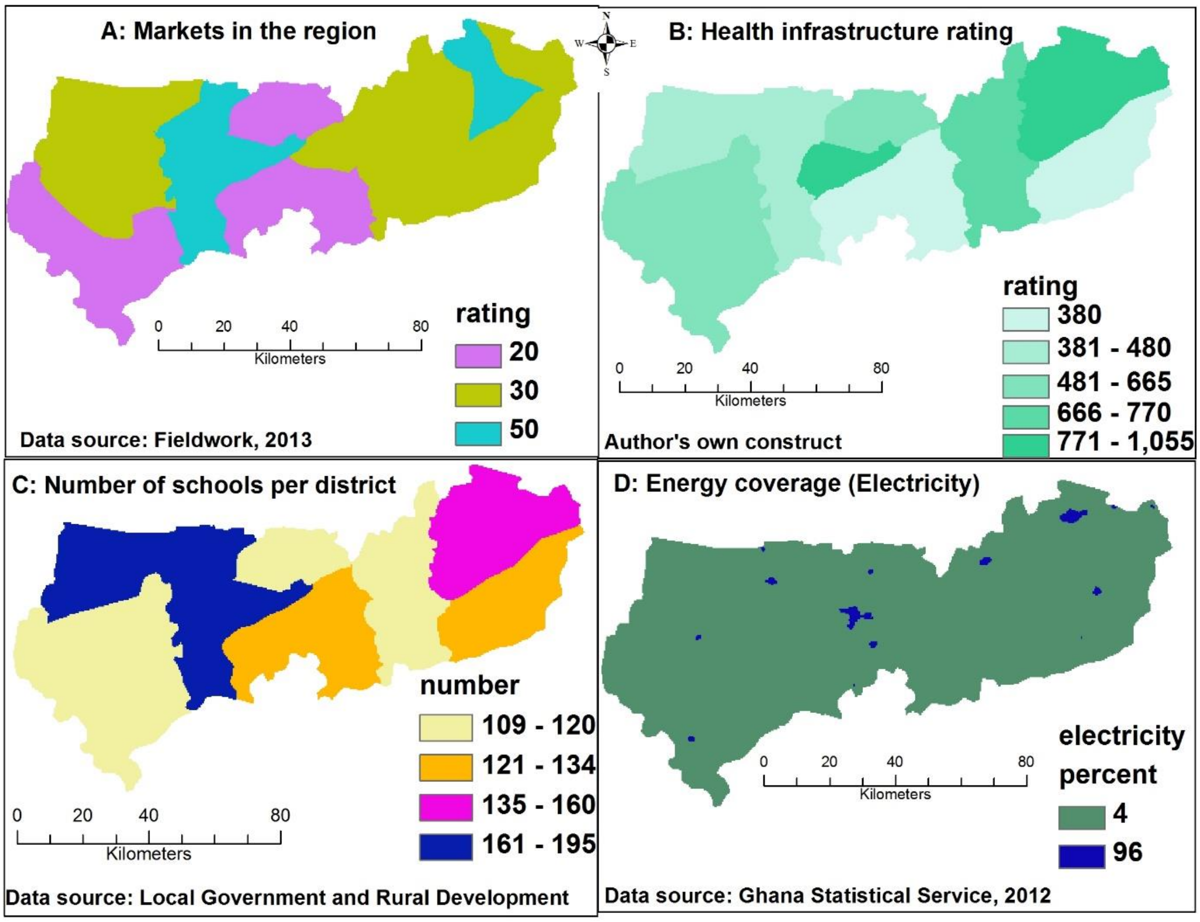


Fig. 6.13 Maps of infrastructural coverage

6.3.2.4 Coping strategies

Remittances received from relatives living outside of the districts were used as a measure of coping. This was considered a coping strategy because as presented in chapter 5, the remittances received were largely used for buying food, agricultural inputs or to rebuild/rehabilitate housing units. Thus, from the questionnaire survey, the percentage of households receiving remittances specifically for coping with disaster was extracted and used to map this indicator. Most of the remittances go into buying food and help the people cope with food shortfalls from their own production and consequently crop failure. Another coping strategy was rearing livestock and selling them off in times of need. The dataset to map livestock owning was derived from the WFP (2012) report which were district level data. From the dataset, households with large livestock ownership had more coping capacity since they can sell more than those with lower numbers. The livestock ownership did not include poultry in this case because incomes from poultry are generally low.

Also, the people are engaged in income generating activities such as food processing, petty trading, corn mill operations, etc. which yield additional income to support the household. The average number of household members engaged in income generating activities was used to map this indicator. Districts or areas with high percentages are assumed to be more resilient than those with low values. This dataset was obtained from the WFP report and used. Another indicator identified was food aid. The dataset to map this indicator was obtained from the WFP report. It showed the percentage of households receiving food aid in each district. The reasoning behind the use of this dataset was that the households receiving food aid increased their coping strategy to cope with food shortage as a result of low production from farms. Thus districts with a higher percentage of households receiving food aid had a higher coping capacity than those with lower percentages. The maps for coping capacity are shown in Fig. 6.14.

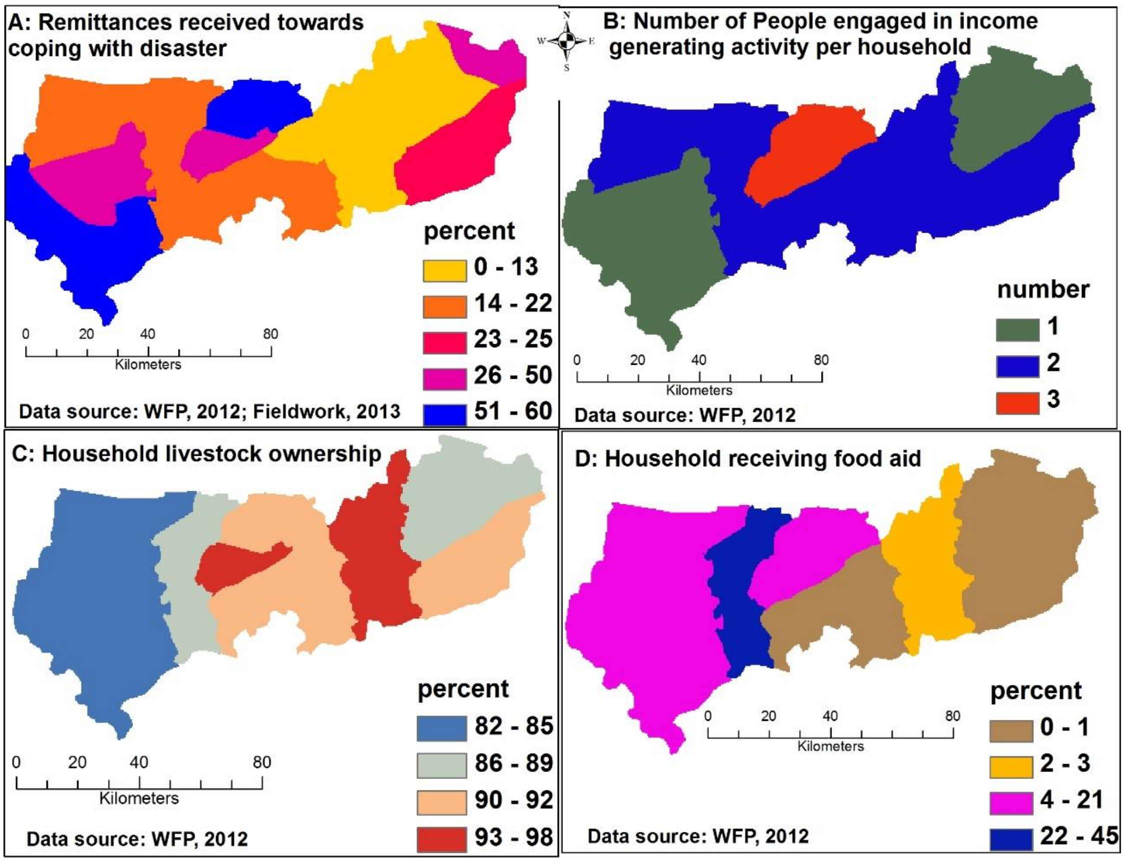


Fig. 6.14 Coping capacity of households in the districts

6.4 Normalisation and transformation

The indicators mapped above are in different measurement units and therefore, before the aggregation to sector susceptibility or adaptive capacity layers, they have to be brought to a uniform dimension to avoid problems with mixed units. The process of bringing data to the same dimension so they can be compared is called normalisation. There are several procedures for normalising data but in this research, the scale range method was used (see Malczewski, 2000; Nardo *et al.*, 2005). The equation for the normalisation is:

$$\text{Normalised value} = \frac{\text{old value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}} \qquad \text{..................... 6. 4}$$

Where old value is the value to be normalised, and minimum value and maximum value are the minimum and maximum values respectively in the range of values to be normalised. This normalisation procedure results in all values lying between 0 and 1. The choice to use the scale range method over the other most commonly used standardisation method was because it avoids the use of positive and negative values of an indicator in the aggregation process which makes interpretation of the results of equation (2) more complex. Most of the normalised values were not transformed because the higher values indicated higher susceptibility and higher adaptive capacity. Those indicators that were transformed were those where higher values meant less susceptibility. The population, length, area and all absolute values (e.g. number of dams) were converted to number per grid (e.g. population per grid or population density) before normalisation. The percentage values, crop sensitivity index and the categorical scale values, particularly those below 100 were not converted to number per grid because these relative values.

Normalisation is also fraught with problems. It suppresses the existence of extreme values. This implies data with a wide range of values will be scrambled into a narrow range leading to a loss of information (Abson *et al*., 2012). With the normalisation process, when new information is available, an adjustment of the analysis period t, which may, in turn, affect the minimum and the maximum for some sub-indicators (q) for country (c) and, therefore, the values of the I^{t}_{qc} themselves. In such cases, to maintain comparability between the existing and the new data, the composite indicator would have to be recalculated for the existing data (Nardo *et al*., 2005). Also, normalisation also leads to the calculation of indices with dimensionless units which may be difficult to understand by policy makers. This can be overcome by always going to back to look at the original indicators used to construct the vulnerability index and this has been adopted to analyse vulnerability in Chapter 7.

Rescaling also rewards extremes values but this is normally overcome by taking 2.5% off the data at both ends. However, in this research is was not applied because all the data used here were discrete.

6.5 Weighting and aggregation

The combination of indicators to form composite indicators needs to be done in a meaningful way. This means that a decision on which weighting model to use and which aggregation procedure to apply must be made. There are several weighting methods but in this research different weighting procedures were used based on the impact of the hazard (see Nardo *et al.*, 2005). The weighting process is central to the construction of composite indicators and an approach similar to the Analytical Hierarchical Approach (see Nardo *et al*., 2005) was used to develop the weights.

The weights of the indicators of each hazard on the various livelihood activities of the people were first obtained at the sector level and then at the hazard level. These were obtained from the field survey where each participant (in the questionnaire survey, focus group discussions and institutional survey) was asked to rank the effects of the hazards on the livelihood activities based on the losses incurred if the hazard occurred. It must be mentioned that the weights attached are averages. The reasons for assigning the weights obtained from the analysis of the field survey, as well as the literature, are given in Table 6.6. The sum of the weights at each level must be equal one (1) (Malczewski, 2000). To aggregate the data at sub-domain level, the overlay operation used was the weighted linear sum. This method combines data from different criteria to create a single index.

Table 6.6 Weights of susceptibility indicators and the reasons for the weights

Drought/high temperature		
Sector[23]/Indicators	**Weight**	**Reasons**
Agriculture	**0.6**	Main economic activity and everything depends on it
Crops	0.6	Because crop production is their major livelihood activity
Livestock (pasture)	0.3	Livestock keeping is a supporting activity, data quality
Water holding capacity	0.1	Data quality
Health	**0.3**	Health burden and food insecurity
Food insecurity	0.4	Affects general welfare and income
population distribution	0.1	General health of the population
CSM	0.2	Treatment available, options to avoid it
Employed in agriculture	0.3	Affects income
Water	**0.1**	Have experienced water crises within the study period
Surface water	0.8	Easily dries out, livestock deaths,
Ground water	0.2	Still get water in drought years
Flood/high precipitation		
Health	**0.4**	Displaces people, food insecurity, affects human mentally, physically (i.e. labour) and financially
Displacement	0.1	Many people have moved away from river
Casualties	0.2	Presence of early warning has reduced deaths
Malaria	0.3	Treatment, bed nets available
Vulnerable group	0.4	Cannot fend for themselves
Agriculture	**0.3**	Food crops destroyed but mainly along river banks, incomes affected
Crops	0.6	Because crop production is their major livelihood activity
Soil loss	0.3	Affects soil fertility, data quality
erosion	0.1	Affects soil fertility, silts water bodies, data quality
Housing	**0.2**	Not frequent and minimal
Buildings destroyed	0.2	Displaces people, affects economic activities
Proximity	0.4	All human activities to rivers suffer most
Flash flood	0.3	It is an urban phenomenon, so high rates from urban respondents
Building material	0.1	Buildings not frequently destroyed
Roads	**0.1**	Seasonal and minimal
First class	0.2	Suffers minimal impact
Second class	0.3	Impact is higher than first class roads
Third class	0.5	Mostly not motorable in the rainy season
Windstorm		
Housing	**0.4**	
Roofing material		Not frequent, destruction not too severe, pull down trees at times

Source (Based on field studies by Author)

[23] Sector and sectoral weights are bolded

The equation for this aggregation method is:

$$CI_d = \sum_{q=0}^{Q} w_q I_{qd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 6.5$$

Where CI =component index, d = sub-domain[24], q = indicator, Q = number of indicators, *w* = weight and *I* = normalised indicator.

The method is one of the most widely used GIS-based methods primarily because it is easy to implement within the GIS environment using map algebra operations and cartographic modeling (Tomlin 1990, Berry 1993 cited in Malczewski, 2000).It is easy to understand and interpret values.

6.6 Conclusion

This chapter set out to develop susceptibility and adaptive capacity layers for vulnerability mapping of the various hazards occurring in the Region. The division of the chapter into susceptibility and adaptive capacity sections largely aided the exercise and made it much easier to devise a weighting scheme. The novelty here is the use of local knowledge to produce weights which has proven to be helpful in the exercise. The agriculture sector suffers more from floods and droughts than the other sectors and in years where both occur simultaneously, the impact is severe. The maps show that the susceptibilities and adaptive capacities of the sectors vary among the districts for the various hazards and this may produce variation in vulnerabilities. However, the extent and nature of the variation in vulnerabilities is analysed in the next chapter by aggregating the layers developed in this chapter.

[24] Sub-domain represents susceptibility, adaptive capacity, sector or hazard

Chapter 7 Vulnerability mapping and analyses

7.1 Introduction

Vulnerability varies across space and time and also among livelihood activities for different hazards. The objective of this chapter is thus twofold; to show the spatial variation in vulnerability across sectors and to explain the variations. This will be achieved by bringing together the susceptibility and adaptive capacity layers developed in chapter 6 to map vulnerabilities and discuss the resulting maps. Therefore the chapter will be divided broadly into visualising and analysing vulnerability.

7.2 Visualising vulnerability

Vulnerability is the algebraic sum of susceptibility and adaptive capacity with one opposing the other (i.e. adaptive capacity reduces impacts or susceptibilities and hence vulnerability). The term susceptibility connotes adverse effects. Thus, in this research, it is argued that this term should be negated. The equation for determining vulnerability in this research is:

$$\textit{Vulnerability} = -(\textit{Susceptibility}) + \textit{Adaptive capacity} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7.1$$

This conceptualisation will result in negative values (vulnerability) for grid cells with susceptibility values larger than the adaptive capacity values and positive values (resilience) where the susceptibility values are smaller than the corresponding adaptive capacity values. To operationalise the concept of vulnerability as shown in equation 7.1, Fig. 7.1 was used. The susceptibility layers were aggregated at sector level with weights as shown in Table 6.6 in chapter 6. The adaptive capacity layers as shown in Fig. 7.1 were aggregated at two levels, first to form social capacity and resilience and then combined to form the composite adaptive capacity.

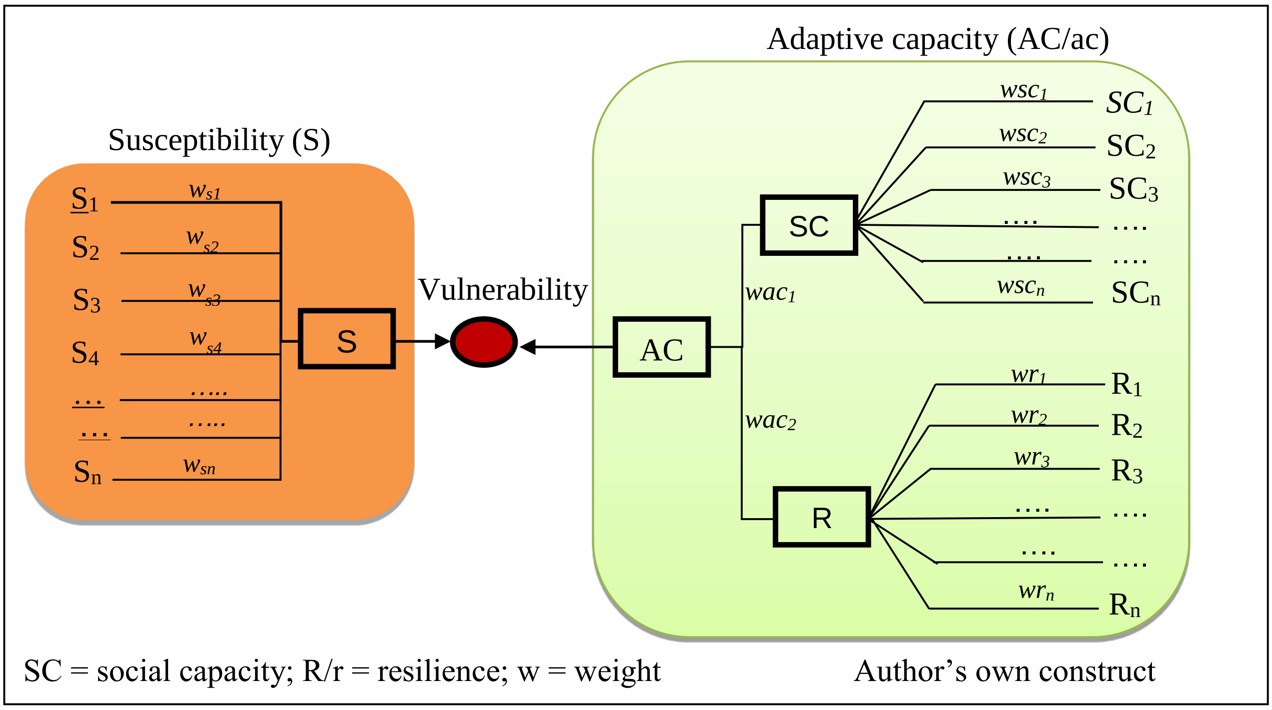


Fig. 7.1 Aggregation of indicators for vulnerability mapping

7.2.1 Sectoral vulnerability

To map the vulnerability of the various sectors to droughts/high temperatures, the susceptibility layer for each sector was combined with the necessary adaptive capacity indicators. These indicators were derived from the field survey as well as those that exist in the literature and are being used in the Region to adapt to the hazards. The adaptive capacity indicators were assumed to be of equal importance to the sectors and therefore, equal weighting was applied in their aggregation with the susceptibility layer. This was done because there was insufficient knowledge about the causal relationship between the adaptive capacity indicators for each sector and the indicators were selected in such a way that correlation (double counting effect) was reduced greatly. Thus, the use of principal component analysis or any statistical model which depends on correlation was not appropriate (Nardo *et al*., 2005). The maps are presented first for each sector and then added up to obtain the overall vulnerability to each climatic hazard.

For the agriculture sector, the adaptive capacity indicators used are presented in Table 7.1.

Table 7.1 Adaptive capacity indicators for sectoral vulnerability mapping to drought/ high temperatures

Sector	**Indicator**	**Reason(s) for its use**
Agriculture	Remittances (R)	Financing of agricultural activities
	Wealth (SC)	Finance agricultural activities
	Financial institutions (SC)	Provide credit for agriculture and other activities
	Markets (R)	Trading of inputs and outputs
	IGA (R)	Provide alternative income to assist finance farming
	Investment opportunities (SC)	Provide alternative source of employment
	Animal ownership (R)	Sell to buy agriculture inputs, use for ploughing
	NGOs (SC)	Capacity building and finance
	Institutions (SC)	Offer extension and other services
	Irrigation facilities (R)	Irrigate land for farming
	Skills (SC)	As an alternative source of employment
	Protected land (R)	Ecosystem integrity and moderating evapotranspiration
	Land availability (R)	For agriculture and related activities
	Literacy (SC)	Increases chance of formal employment
Health	IGA (R)	Alternative income, finance healthcare and buy food
	Wealth (SC)	Finance healthcare
	Literacy (SC)	Increase awareness of health issues
	Skill (SC)	Increase employment opportunities and generate income to finance healthcare
	Health facilities (R)	Provide healthcare and related services
	Energy (R)	Power the cooling systems
	Markets (R)	Sell produce and buy medications
	Food aid (R)	Supplement food supply
	Remittances (R)	Buy food and pay for healthcare
	Animal ownership (R)	Sell and buy food
Water	Institutions (SC)	Source funding for the construction of water points
	Investment opportunities (SC)	Provides opportunities for investment in the water sector
	Skills (SC)	Generates income for buying water
	NGOs (SC)	Provision of boreholes, dams/dugouts
	Wealth (SC)	Finance water provision
	Energy (R)	Pump water to users
	IGA (R)	Additional income to the finance water provision

Source: Based on field studies by Author N.B: IGA = income generating activity; SC =social capacity; R= resilience

Three sectors supporting the livelihoods of the people were identified to drought/high temperatures and the vulnerability maps of these sectors are shown in Fig. 7.2. The figure suggests that when there is a drought the agriculture sector suffers the most. From the range of values, it has the largest negative value and completely in the negative indicating that it is highly vulnerable to drought. The second most highly vulnerable sector was the water sector as it had next largest negative values but showed a higher resilience than the health sector. The high level of resilience is due to high groundwater recharge rate and the fact that the Region largely depends on groundwater for domestic and, to some extent, agricultural use (Anayah and Kaluarachchi, 2009).

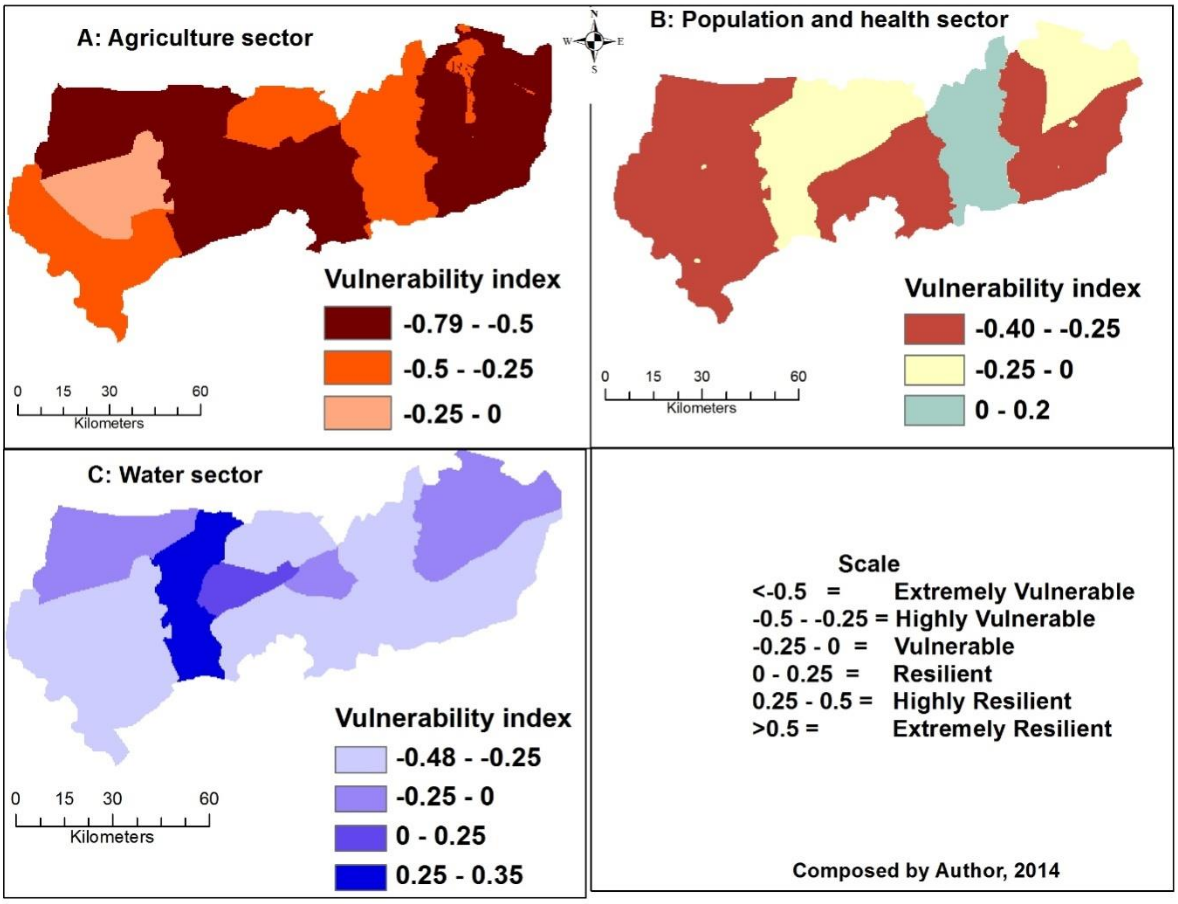


Fig. 7.2 Vulnerability of sectors to drought/high temperatures

Most of the participants in the questionnaires survey stated that since they started using boreholes and/or mechanised wells, they have not experienced any major water problems, thus confirming the finding here. The health sector shows low vulnerability due to the presence of good adaptive systems such as health facilities, inflow of remittances from relatives to buy food and finance health and food aid from the government and international donors. In mapping the vulnerability of the identified sectors to floods, the adaptive capacity indicators in Table 7.2 were used.

Table 7.2 Adaptive capacity indicators for vulnerability of sectors to flood

Sector	Indicator	Reason(s) for its use
Agriculture	Remittances (R)	Financing of agricultural activities
	Wealth (SC)	Financing of agricultural activities
	Markets (SC)	Trading of inputs and outputs
	IGA (R)	Provide alternative income to finance farming
	Animal ownership (R)	Sell to buy agriculture inputs, for ploughing
	NGOs (SC)	Capacity building and finance
	Institutions (SC)	Offer early warning, extension and other services
	Irrigation facilities (R)	Irrigate land for farming
	Skills (SC)	As an alternative source of employment
	Literacy (SC)	Increases chance of formal employment
Health	IGA (R)	Provide alternative income to assist finance healthcare and buy food
	Wealth (SC)	Finance healthcare
	Health facilities (SC)	Provide healthcare and related services
	Land availability (R)	For relocating human activities
	Markets (R)	Sell produce and buy medications
	Food aid (R)	Supplement food supply
	Remittances (R)	Buy food and pay for healthcare
	Animal ownership (R)	Sell and buy food
	Skills (SC)	As an alternative source of employment
	Literacy (SC)	Increases chance of formal employment
	NGOs (SC)	Provide food aid and relief, capacity building
	Institutions (SC)	Provide food aid, relief and temporary shelter
	Early warning (SC)	Sound alarm and prepare people for hazard
Housing	Institutions (SC)	Source funding for the construction of water points
	Remittances (R)	Finance building, rent, etc.
	Wealth (SC)	Finance building, relocation, etc.
	Literacy (SC)	Increases chance of formal employment
	NGOs (SC)	Provide food aid and relief, capacity building
	Skills (SC)	As an alternative source of employment
	IGA (R)	Additional income for household activities
	Land availability (R)	Space for building, construction materials
Road	Land availability (R)	For construction of roads and obtaining construction materials
	NGOs (SC)	Source funding for gravelling of feeder roads
	Institutions (SC)	Secure funding for road construction

Based on field studies by Author N.B: IGA = income generating activity

On the part of floods, four sectors were identified; agriculture, health, housing and roads. There was insufficient information to determine the susceptibility of the water sector to flood and therefore the water sector was left out. Similarly, as stated in the case of adaptive capacity indicators for the agriculture sector, equal weights were used. The vulnerabilities of these sectors were examined spatially through the use of the maps in Fig. 7.3.

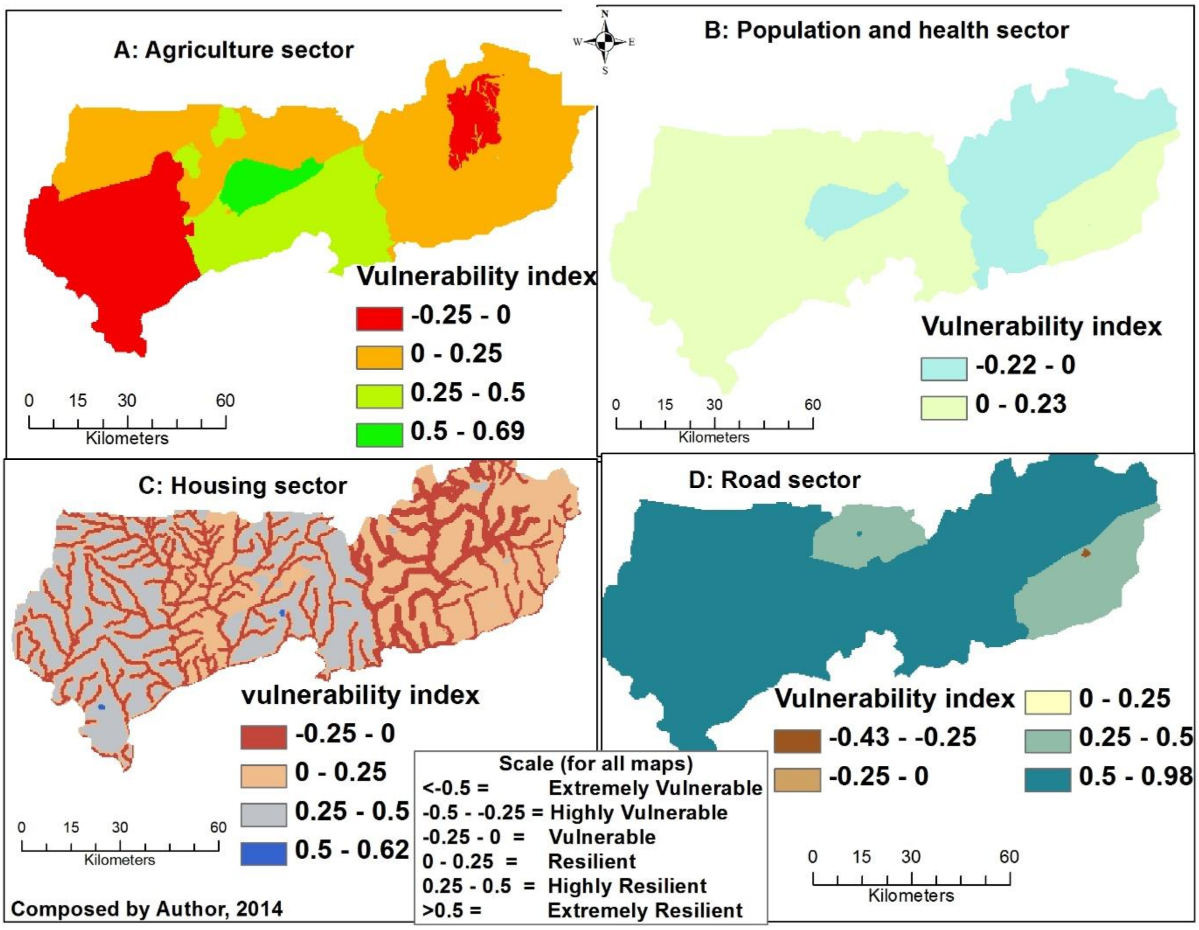


Fig. 7.3 Map of vulnerability to floods/high rainfall according to geographical sectors

From the figure, the south western part of the Region (Builsa Districts) and the Binduri District are vulnerable to flooding/high rainfall while the Talensi, Nabdam and parts of the Bolgatanga municipal are highly resilient to flooding in the agriculture sector. The health sector shows vulnerability around Bawku West, Binduri, Pusiga Districts and Bawku and Bolgatanga Municipals while the rest of the Region is resilient. For the housing sector, the vulnerability is along the rivers/streams with the western and central parts of the Region showing high resilience to flooding/high rainfall. The road sector does not show any vulnerability except a small portion close to Garu town which could attributed to a bridge that was washed away, cutting off Garu from Bawku in 2007. During the period in which the bridge was dysfunctional, an alternative route was used to link the town and Bawku and this has become the main route now. To show the overall vulnerability to droughts/high temperatures and floods/high rainfall, the maps were combined using the weighting in Table 7.3. These weights were obtained from the field work.

Table 7.3 Weights for aggregate vulnerability mapping

	Sector				
Hazard	Agriculture	Health	Housing	Water	Road
Droughts/high temperatures	0.6	0.3		0.1	
Floods/high rainfall	0.3	0.4	0.2		0.1

Source (Based on field studies by Author) empty space means was not considered in mapping that hazard

The maps in Fig. 7.4 show that the Region is highly vulnerable to droughts/high temperatures and just vulnerable to floods/high rainfall. Indeed, the Region shows resilience to floods/high rainfall but is highly vulnerable to droughts/high temperatures. This is due largely to the fact that the agriculture sector, which is the main economic activity and also the main source of food for the people, suffers more when there is a drought than a flood. It must be mentioned here that resilience does not mean that flooding is not disastrous in the Region. What it shows is that some parts of the Region do not get floods but these areas are still vulnerable to high rainfall as buildings collapse and crops may fail to seed if the rainfall is heavy, particularly if rain comes daily at the flowering and seeding stages. This is why it is not a perfect resilience with a value of one (1). The same interpretation can be deduced for the droughts/high temperatures.

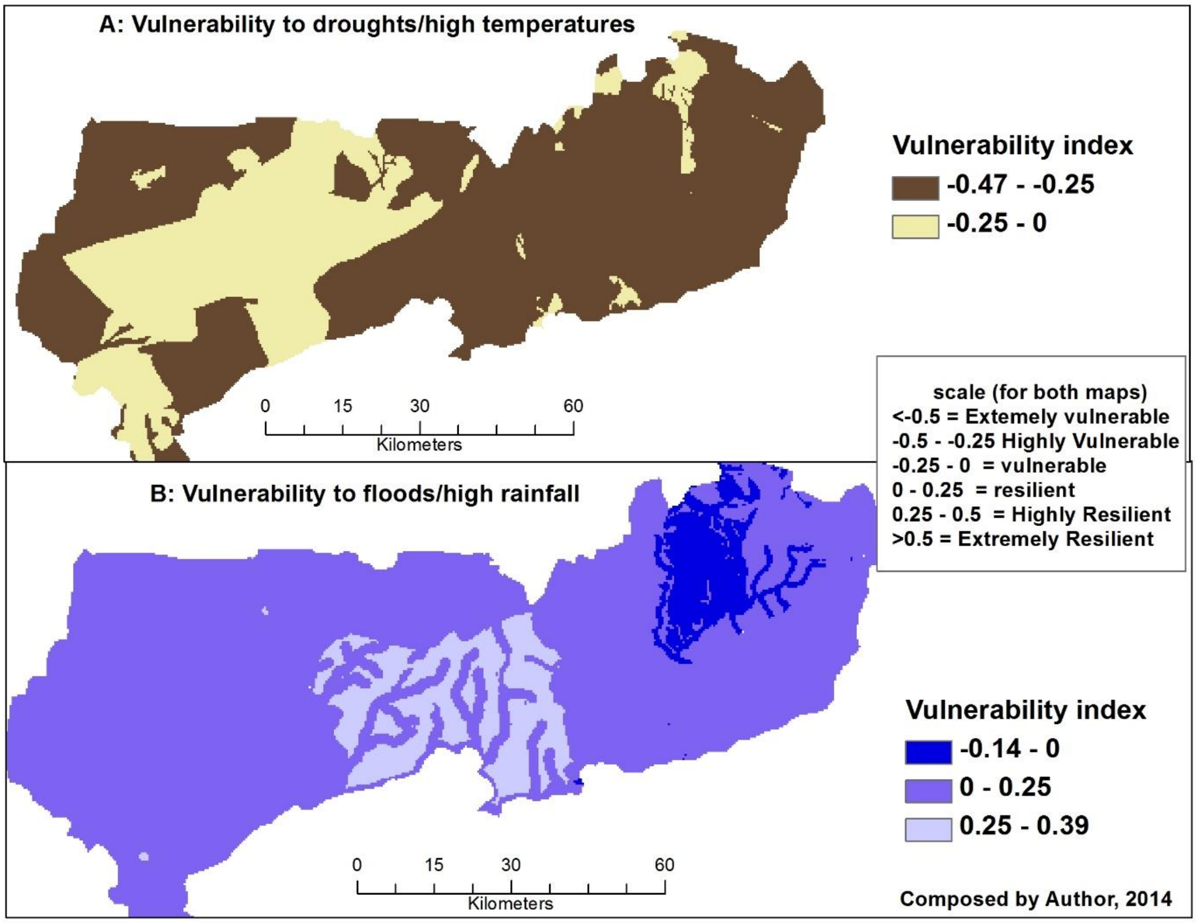


Fig. 7.4 Map of Vulnerability to droughts/high temperatures and floods/high rainfall

The vulnerability of the Region to windstorm was mapped combining its susceptibility to wind with the following adaptive capacity indicators: wealth, income generating activity, institutions, NGOs, remittances and early warning systems with the same reason(s) as in Tables 7.1 and 7.2. The resultant map is shown Fig. 7.5. From the map, it can be seen that the entire Region is resilient to windstorms especially in the urban areas where resilience is high. This is because windstorms mainly affect roofs and the rural roofs which are largely thatch suffer more from winds. Thus among the hazards, windstorms are manageable in the Region followed by floods/high rainfall and droughts/high temperatures. This confirms the assertion by the regional NADMO Coordinator that the foremost hazard in the Region is drought.

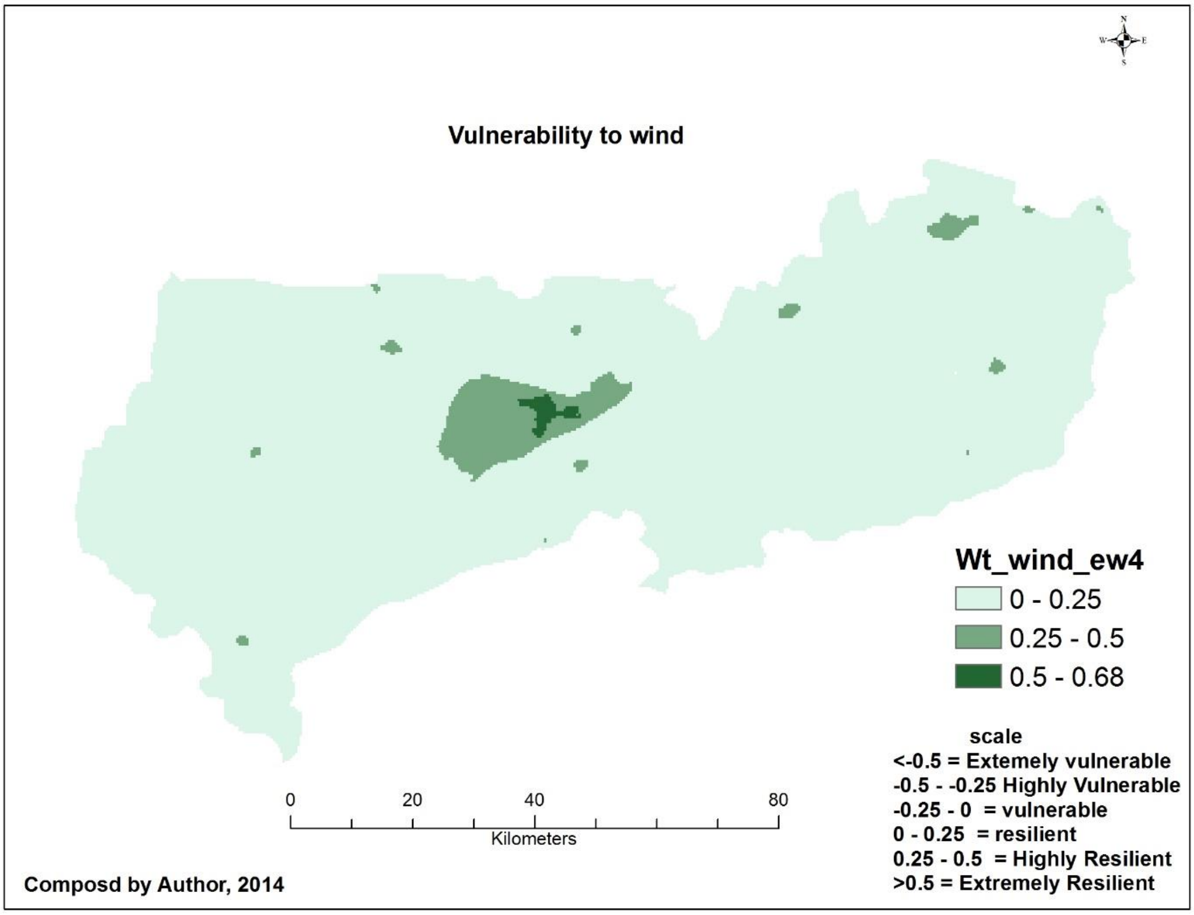


Fig. 7.5 Vulnerability map of the Upper East Region to windstorms

7.2.2 Spatial vulnerability

The analysis above shows that all the sectors in the Region are vulnerable to the hazards identified albeit to varying degrees. To analyse the spatial variability of vulnerability, the district was considered as the unit of analysis since most of the datasets were derived at district level and also, it is the unit for planning and implementation of interventions. Mean zonal statistics for each of the vulnerability maps was calculated to analyse the vulnerability of each sector to the hazards in the districts. The problem with this method is that it averages the scores and therefore cut off high and low values. But this effect is minimised by the kind of social networks in place where the people support each other in terms of food, labour, temporary accommodation, etc. It must be however, mentioned that modernity and globalisation is changing these value systems towards more individualistic and personal stance such that support is waning. The mean zonal maps are shown in Fig. 7.6.

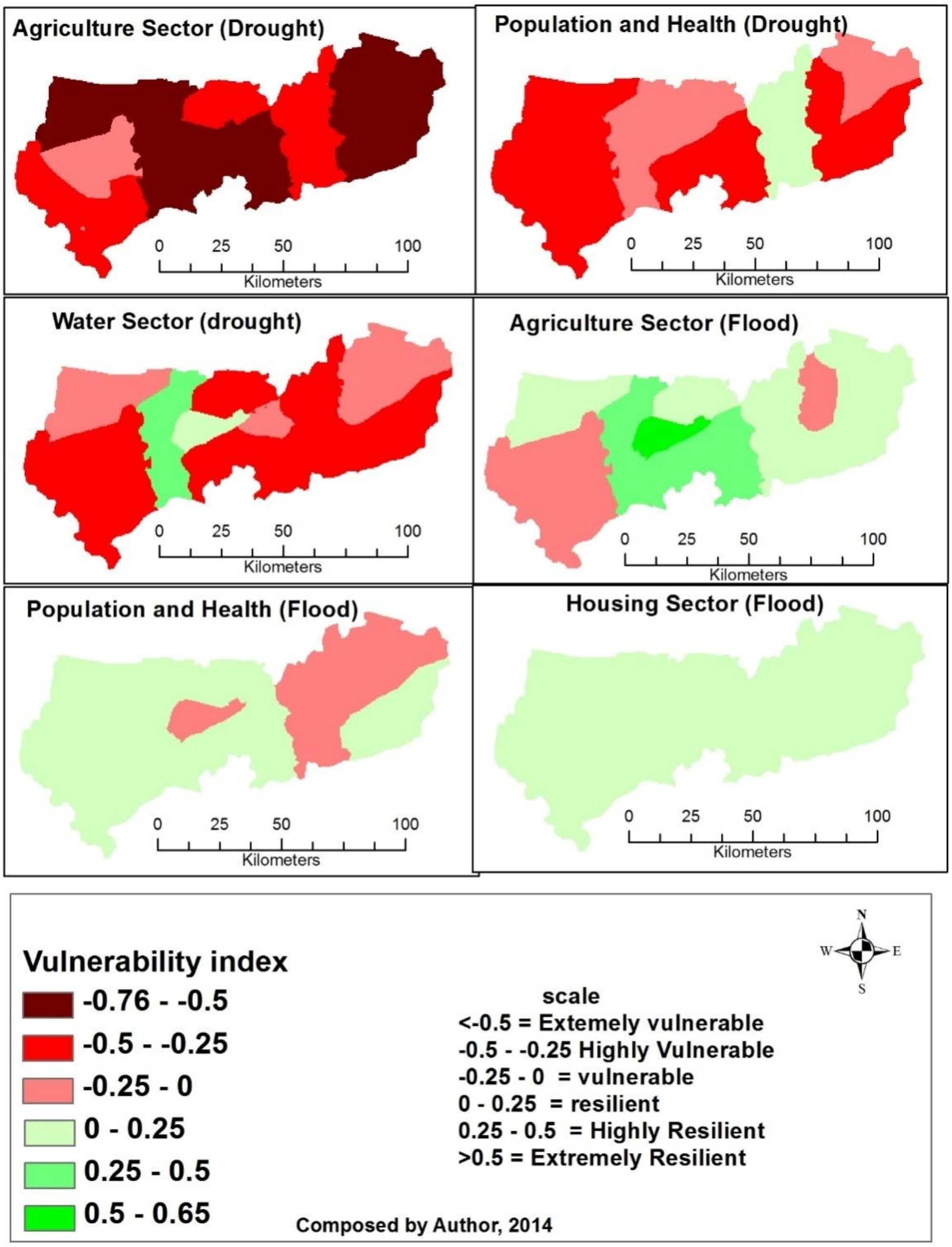


Fig. 7.6 Map showing spatial variation of vulnerabilities of the various sectors

From the figure, the vulnerabilities of the various sectors vary in the districts. Thus, the discussions on vulnerabilities will be done per district but for expediency, they are grouped into six districts; namely Bawku East, Bawku west, Bolgatanga, Bongo, Builsa and Kassena-Nankana Districts, representing the districts that existed before 2005.

7.2.2.1 Bawku East Districts

The Bawku East Districts comprise Binduri, Garu-Tempane and Pusiga Districts and Bawku Municipal. All these districts are highly vulnerable to droughts/high temperatures in the agriculture sector. Garu-Tempane and Binduri are highly vulnerable in the health sector while Bawku and Pusiga are low in vulnerability. For the water sector, Garu-Tempane shows high vulnerability with the others having low vulnerability. This shows that Garu-Tempane is most vulnerable, followed by Binduri with Bawku and Pusiga at the almost same level. This high vulnerability of the Garu-Tempane District could partly explain its position as being among the three most highly food insecure districts in the Region (WFP, 2012). With regards to floods/heavy rainfall, only Binduri shows low vulnerability to floods in the agriculture sector, the rest are resilient. In the case of the health sector, Garu-Tempane is resilient with the rest showing low vulnerability while all are resilient in housing sector.

The high vulnerability to droughts in agriculture could be attributed to exposure of the soil to the sun resulting from crop residue removal (Yiran *et al.*, 2012) and the low number of dams/dugouts in the districts. The exposure of the soils coupled with low water retention capacity of the soil causes soil moisture to evaporate quickly after rains. A study by Oguntunde (2004) found that nearly 80% of rainfall in the savannah is lost to evapotranspiration in the rainy season and this is a problem in this study area. This means that only 20% of rainfall is available for plant growth. Thus, the crops are highly susceptible (exposed and sensitive) to droughts/high temperatures more often resulting in crop yield losses.

The districts also have low adaptive capacities to face these challenges in the agriculture sector as there are fewer dams for irrigation and watering of livestock in each district, and household land sizes are small due to population growth. Other livelihoods assets (e.g. remittances, income generating activities, pasture land, employments, etc.) as well as institutional structures to enhance adaptive capacities in the districts are also low. Bawku being the former capital of these districts has better infrastructure and institutional arrangements than all the others and therefore has better adaptive capacity. However, this research found potential opportunities in tanning, large clay deposits for pottery and bricks, the large animal markets, production of onions, etc. which if given the necessary support could employ a lot of people in the districts and enhance adaptive capacity.

7.2.2.2 Bawku West

The Bawku West District shows high vulnerability to droughts/high temperatures in the agriculture and water sectors and resilient in the health sector. The soils in this district have better water retention capacity than the Bawku East Districts and therefore the crops are less susceptible to droughts/high temperatures though they also face the same high evapotranspiration rates. It also has relatively higher number of dams/dugouts than each of the Bawku East Districts. In the case of flooding, it shows low vulnerability in the health sector and is resilient in all other sectors. Adaptive capacity too is low but there is potential in the mining sector and in production of onion, guinea fowl and water melon.

7.2.2.3 Bolgatanga Districts

The Bolgatanga Districts comprise Bolgatanga Municipal and Talensi and Nabdam Districts. All three districts are highly vulnerable to droughts/high temperatures in the agriculture sector. The Talensi and Nabdam Districts are highly vulnerable to droughts/high temperatures and the Bolgatanga Municipal show low vulnerability in the health sector. In the water sector, the Talensi District is highly vulnerable, Nabdam is low and Bolgatanga Municipal is resilient to droughts/high temperatures. In all sectors, Talensi is most vulnerable followed by Nabdam and then Bolgatanga. The high vulnerability of Talensi-Nabdam partly explains why is it one of the three highly food insecure districts in the Region (WFP, 2012). The vulnerabilities to floods/heavy rainfall hand is low in the Bolgatanga Municipal for the health sector but resilient and highly resilient in the housing and agriculture sectors respectively. The Talensi and Nabdam Districts are resilient in the health and housing sectors and highly resilient in the agriculture sector.

The generally strong performance of the Bolgatanga Municipal is due to its relatively high adaptive capacities compared with the other districts as it has better infrastructure and institutions. Bolgatanga has hospitals and many other health facilities, and is close to the Vea dam which has a sizeable portion of its irrigable area in the district. The Talensi and Nabdam Districts have no hospital but some few health facilities, and only a few dams/dugouts. All districts have gold deposits. The Talensi District also has a quarry and rocks which can be harnessed for production of tiles and improve adaptive capacity in the district. All these districts need more dams/dugouts and groundwater use for irrigation to reduce reliance on rainfed agriculture.

7.2.2.4 Bongo District

This district is highly vulnerable to droughts/high temperatures in the agriculture and water sectors and has low vulnerability in the health and housing sectors. It is resilient to floods/heavy rainfall in all sectors. The reason for its general low vulnerability is that the soils have relatively high water holding capacity and it also has a high number of dams/dugouts for irrigation and watering of animals. In fact, the second largest dam is located in the district and it has the second highest number of dams after Kassena-Nankana East District in the Region. Thus, crops are able to withstand droughts for a little longer than in other districts and thus, the low crop sensitivity. Dry season farming in the district is also better than many other districts in the Region. However, as seen in other districts, adaptive capacity is low though there is high potential in quarrying and processing of granite rock material into tiles in the district.

7.2.2.5 Builsa Districts

The Builsa North and Builsa South Districts constitute the Builsa Districts and occupy the western part of the Region. While the Builsa North show low vulnerability to droughts/high temperatures, the Builsa South is highly vulnerable in the agriculture sector. Both are highly vulnerable in the health and water sectors. Both districts are resilient to floods/heavy rainfall in all sectors except the agriculture where their vulnerability is low. These districts have large tracts of land for both crop and animal farming and the soils have good water retention capacity. The Fumbisi rice valleys are particularly suitable for rice production. The Builsa North had a higher number of dams/dugouts than the South. Thus, the susceptibilities of these districts seem the same but vulnerability varied because of variations in adaptive capacity. Because the Builsa North houses the capital of the former Builsa districts, most of the NGOs and financial institutions serving the two districts are located there. There are also potentials in mining gold, clay and other minerals which are untapped.

7.2.2.6 Kassena-Nankana Districts

The Kassena-Nankana East and West Districts are highly vulnerable to droughts/high temperatures in the agriculture sector. In the health sector, the Kassena-Nankana West is highly vulnerable while the Kassena-Nankana East shows low vulnerability. In the water sector, the west shows low vulnerability while the east is highly resilient. It therefore follows that the Kassena-Nankana West is relatively more vulnerable to droughts than Kassena-Nankana East. Again, this could partly explain why the Kassena-Nankana West is among the three most highly food insecure districts in the Region (WFP, 2012). The high vulnerability in agriculture is due to the high evaporation rates and the low water holding capacities of the soils. However, the Kassena-Nankana East has a high number of dams/dugouts and a higher numbers of people engaged in productive irrigation than the West. The strong perfomance of the Kassena-Nankana East is also due to its relatively good infrastructure. These districts have potential in tourism, basketry, blacksmith, pottery, cotton spinning, etc.

7.3 Evaluation

Evaluating a composite index is one of the most important steps in a quantitative vulnerability assessment as both the development of indicators and the building of a composite index inherits numerous uncertainties (Damm, 2010). This is because all the steps taken during the development of indicators from gathering of data and information from various sources, scaling of data, and finally the selection of a normalisation, weighting and aggregation technique involve subjective decisions that severely contribute to the existence of uncertainties (Nardo *et al.*, 2005). It is stated by Nardo *et al.* (2005:81) that "good modeling practices require that the modeler provides an evaluation of the confidence in the model, assessing the uncertainties associated with the modeling process and the subjective choices undertaken, since the quality of a model depends on the soundness of its assumptions". Therefore, in this section, the robustness, sensitivity and uncertainty of the indices are assessed.

7.3.1 Robustness tests

The robustness of the composite indices and the reliability of the calculation model were tested by comparing different normalisation, weighting and aggregation procedures. The purpose of this is to find out whether different techniques produce high variance in the composite indicator and hence the stability of the composites. Although all indicators were tested, the agriculture sector is presented here for illustrative purposes.

The rescaling method was tested by using the standardised score normalisation which normalises indicators to have a mean of 0 and standard deviation of 1. The equation used for standardisation is Standard score = $\frac{Value - mean}{standard\ deviation}$. (Nardo *et al.*, 2005)

The normalised standardised score values for each indicator were aggregated by the weighted sum method. The weighting technique was tested by assigning equal weights to all variables. The advantage of this method is that no subjective interpretation or pure mathematical method is used in producing the weights. The method is also easy to understand, reproducible and disguises the absence of statistical or empirical facts (Nardo *et al.*, 2005). Thus, equal weights were assigned to each rescaled input variable and the variables were aggregated to compute the composite vulnerability index. Finally, geometric aggregation was performed to test the robustness of the selected additive aggregation technique. Whereas additive methods compensate for the poor performance in some indicators by sufficiently high values of other indicators, the use of a geometric aggregation is an in-between solution (Damm, 2010). The geometric aggregation is a multiplicative technique involving the use of the equation 7.2:

$$CI = \prod_{q=1}^{Q} X_q^{w} \quad \ldots 7.2$$ (Nardo *et al*., 2005)

CI = Composite Indicator, q = sub-indicator, w = weight associated to sub-indicator

According to Nardo *et al*. (2005), linear aggregation rewards indicators proportionally to their weights, while geometric aggregation favours those indicators or subcomponents with higher scores. Thus, compensability is constant in linear aggregation, while it is smaller in geometric aggregation. The results of the robustness tests are shown in Fig. 7.7. As can be seen in the figure, the same high vulnerability areas are indicated in each pair. It can also be observed that the vulnerabilities exhibit the same patterns although there are variations across the Region. The mean volatility between the various methods was computed to determine the significance of the variations (Table 7.4). According to Groh *et al.* (2007), volatility is determined by the standard deviations of the ranks of an indicator in each country. The mean volatility range from 0.165 for the weighting procedure to 0.24 for the normalisation procedure. The volatilities are small indicating that the normalisation, aggregation and the weighting techniques used in this study are robust.

Table 7.4 Mean volatility of different methods

Method	Normalisation	Weighting	Aggregation
volatility	0.24	0.165	0.17

Source (computed from indicators by Author)

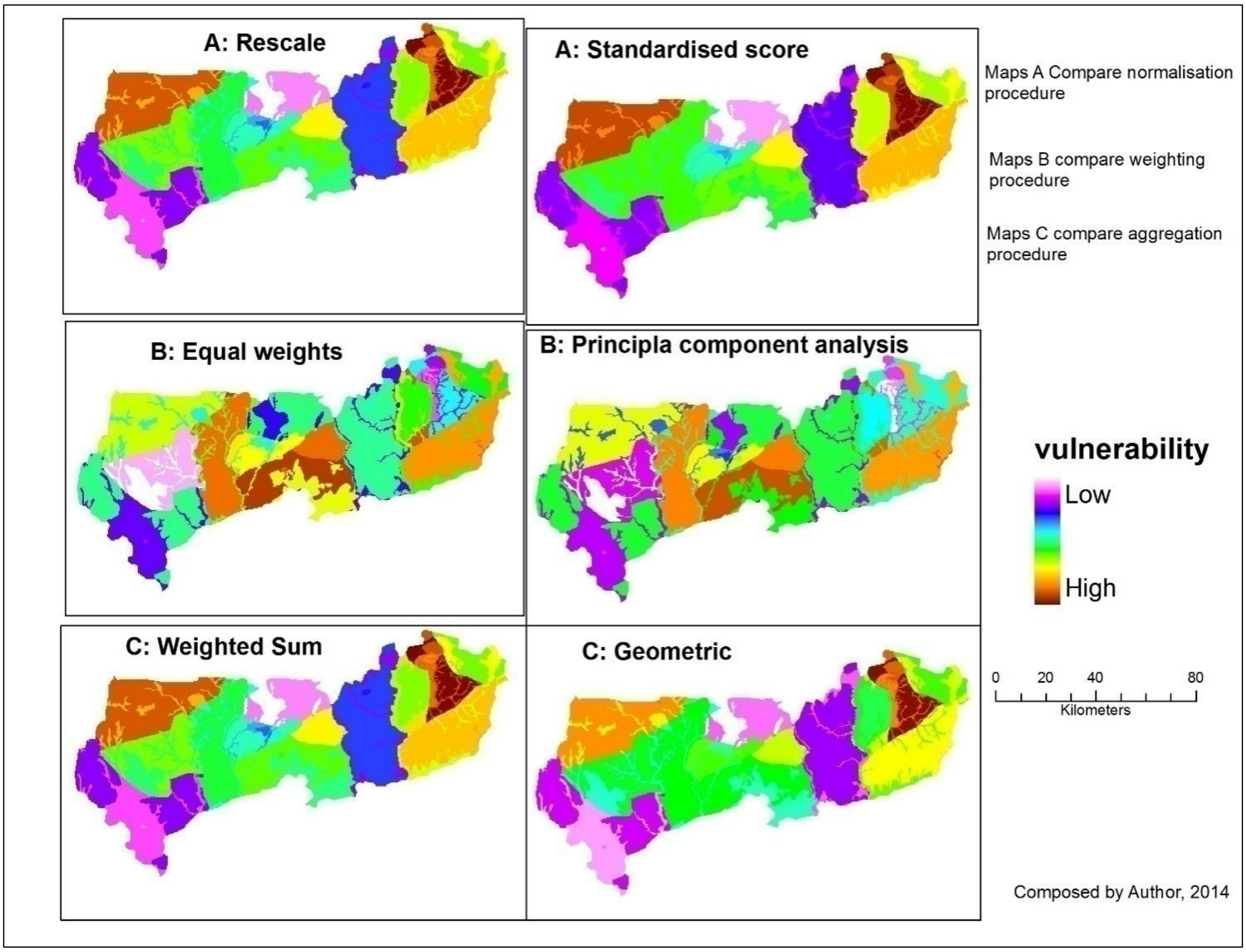


Fig. 7.7 Maps showing test for Robustness

7.3.2 Sensitivity and uncertainty analysis

A sensitivity analysis is performed to determine the contributions, qualitatively and quantitatively, of the different sources of variation in the assumptions to the variation in the output and the dependence of the given composite indicator upon the information used to compose it. The sensitivity analysis is thus closely related to uncertainty analysis which aims to quantify the overall uncertainty in the vulnerability index as a result of the uncertainties in the model input. A combination of uncertainty and sensitivity analysis facilitates the evaluation of reliability and soundness of the vulnerability composite indicator and it improves transparency and starts a debate around the output (Nardo *et al.*, 2005).

Thus, in investigating the sensitivity of the vulnerability composite to any variability in the input data certain indicators have been omitted to explore the impact of variations on the composite indicator. For the agriculture sector, the composite vulnerability was calculated an additional 9 times with, excluding each per run, crop sensitivity, grassland (pasture), water holding capacity (WHC), group of resilience and social capacities indicators, investment opportunities, institutional capacities, land availability and protected land. The mean volatility of the different scenarios were computed as shown in Table 7.5. From the Table, the volatilities range from 0.17 after excluding protected land to 0.21 after excluding crop sensitivity. This means the vulnerability index changed very little after each of the indicators was excluded in turn. Thus the index can be relied on to make judgment on the nature of vulnerability in the Region.

Table 7.5 Mean Volatility of nine scenarios ran with weighted sum technique

Variable changed	Excl. WHC	Excl. pasture	Excl. crop sensitivity	Excl. resilience	Excl. social cap.	Excl. inst. cap.	Excl. invest	Excl. land avail	Excl. Protected land
Volatility	0.2	0.2	0.21	0.19	0.18	0.19	0.18	0.19	0.17

Source (computed from indicators by Author) Excl. = exclude, inst. = institutional; cap. = capacities

7.4 Analysing vulnerability

This section presents a discussion of the maps produced. It is expected that after the discussion, issues which need to be addressed by policy will be identified. Since policies are formulated for specific sectors and the causes of vulnerabilities are similar spatially, discussions will be presented according to the identified sectors. Any discussions that have already been presented in the sectoral and spatial vulnerabilities sections above will not be repeated here.

7.4.1 Agricultural sector

The agriculture sector is highly vulnerable and the most vulnerable, compared with the other sectors, to the principal hazards (droughts/high temperatures and floods/high rainfall) that occur in the Region. The hazards mentioned above, as shown with the SPI (Appendix B), occur frequently and sometimes alternately, from season to season or even both occurring in the same rainy season. From the projections of the IPCC (2014a) which shows increasing frequency and intensities of climatic hazards as the globe continues to warm, the agriculture sector in the Region will continue to suffer major setbacks including crop and livestock production losses. Many studies show a negative correlation between increasing temperatures and yield of major crops in Africa (e.g. Schlenker and Lobell, 2010; Sultan *et al*., 2013). The shortening of growing season will also have great impact on crop production, especially crops that require longer growing period to mature (Thornton *et al*., 2011). Thus, the projected changes in climate in the sub-region will negatively affect crop production in Region and the Savannah ecosystem in general. The reduced growing season length for annual crops and increases in the frequency and prevalence of failed seasons will shift the farming system from a mixed crop-livestock to more livestock production (Jones and Thornton, 2009; Thornton *et al.*, 2010). This will have greater implication for adaptation in the study area where crop production (largely rainfed) is given higher priority over other agricultural production systems (Amankwa *et al*., 2012).

Although there may be a shift from crop production to animal production, climate change and its attendant hazards will impact animal production as well. A study by Sanjak *et al*. (2005) shows that below average rainfall over a 20 years period in North Darfur contributed to degrading grazing and crop lands and reduced food and fodder production resulting in hunger and loss of livestock (cited in AIACC, 2007). Agriculture is the major economic activity in the Region and is seen as the engine for rural growth and a means to achieve poverty reduction (MOFA, 2007). The leading agricultural activity in the Region is crop production which has been shown to suffer losses year after year (see crop failure index in chapter 4). Animal production, the second major agricultural activity in the Region, is also experiencing losses due especially to climatic hazards such as droughts/high temperatures which result in scarcity of water and fodder for the animals. From the analysis of the questionnaire survey, about 80% of farmers lose 3 or more animals when droughts occur. The challenges in agricultural production (crops and animals) are largely attributed to over reliance on rainfall for production which is unreliable and marked with these hazards (IPCC, 2014b). From IPCC (2014b) projections, the agricultural system in Africa is expected to face significant challenges in adapting to the climate change by 2050 as studies show that the negative effect of high temperatures will increase the likelihood of reduced crop yield (Battisti and Naylor, 2009; Burke *et al.*, 2009).

The reduction in crop and livestock production means that incomes will reduce. This could explain the high level of poverty (90%) in the Region (Ghana Statistical Service *et al*., 2009; WFP, 2012) because the frequent production losses mean that farmers are not able to meet production costs. This has a negative implication on the country’s ability to achieve the Millennium Development Goal (MDG) of halving poverty and hunger by 2015. The conclusion of the MDGs is almost upon us, yet the Region continues to suffer from poverty and hunger. A World Food Program study found three of the districts in the Region in extreme food insecurity (WFP, 2012). Official figures also show that 9 out 10 people in the Region are poor (Ghana Statistical Service *et al*., 2009). Thus, all indications are that the Region will not meet the target of the MDG of halving poverty and hunger by 2015. Although Ghana has already met the target of halving poverty nationally, there is no improvement in this regard in the three Regions in northern Ghana which occupy the savannah ecosystem (UNDP, 2012). According to the UNDP report, all the Regions in northern Ghana are in deficit with a deficit of 32 percentage point from the 2006 poverty incidence for the Upper East Region (UNDP, 2012). This represents a retrograde step, away from achieving the MDG in the Region. The high and persistent poverty in the Region limits the capacity to adapt the hazards (Boko *et al.*, 2007).

The good news however is that many government institutions and NGOs in the Region are working to improve the plight of the people. But the institutional representatives mentioned that they are not able to meet their set targets due to limited funding, low staffing and logistics. To some, especially the government institutions, funds are not only inadequate but also do not often come at the right time. At the time of the fieldwork (July-September, 2013), the third quarter in Ghana's financial year, funds for the first quarter had not been released by government to the districts. An agricultural officer mentioned that due to this delay, some field operations are put on hold because there is no money to buy fuel. They also said the world is changing fast in technology and the climate is dynamic, and they need to upgrade the skills of their staff through further training and workshops to meet the new challenges. However, funding is a problem. Though the future of agriculture in the Region looks bleak in terms of climate change and the frequency and severity of its associated hazards to which the agricultural system is highly vulnerable, the experiences gained from the past 30 years could serve as a spring board for adaptation to the hazards if the necessary processes, resources and plans are put in place.

7.4.2 Health sector

Climate change and its associated hazards also have some health implications for the population in the Region. The Bs of Figs. 7.1 and 7.2 show that the health sector is vulnerable to both dry and wet conditions respectively. The dry and hot weather create conditions favourable for outbreaks of cerebrospinal meningitis (CSM). Meningitis occurs in the dry season and is associated with periods of low humidity and the dusty north-east winds that blow over the area from November and terminates with the onset of the rains in May (see Obiakor, 2013). The duration of the epidemic in the African Meningitis Belt (AMB) varies between November and late June depending on the location and arrival of the rains (Whitson, 2005). In Ghana, the mortality rate due to the disease is between 36% and 50% (Owusu *et al.*, 2012). The prevalence of this disease is shown to be increasing in the Upper East Region since 2006 (Ghana Health Service, 2012) and with the prediction of a warming climate, it is likely to be severe. CSM has serious socioeconomic implications for nations as well as the individuals and families affected because of the financial and logistical support required to acquire and distribute vaccines and medicines and a disruption to normal health services in the affected areas (Whitson, 2005). The impact of meningitis is greatly felt in poorer communities and nations (Umaru *et al*., 2013).

The wet conditions (i.e. floods/heavy rainfall) are also associated with outbreaks of malaria which is the number one killer in the Region (Ghana Health Service, 2012). There is evidence of a strong correlation of incidence of malaria with temperature and precipitation patterns (Blanford *et al.*, 2013). Projections from the IPCC (2014b) show that these extreme dry and wet conditions have a high likelihood of increasing in frequency and severity and this will have negative impacts on the population and their health status. Malaria has serious socio-economic implication for nations where it occurs. It also affect nations in terms of low productivity resulting from absenteeism from work and increased health spending (Roll back Malaria, 2011). Malaria burden is more for poor households and communities than the well to do as they lack the financial means to seek proper treatment and also lack access to health facilities (Ricci, 2012). According to WHO (2009), 90% of the global burden of malaria is in Africa.

Food shortage due to agricultural production losses, as mentioned above, causes the people adopt eating practices such as reduced food intake which may lead to malnutrition. The Ghana Demographic and Health Survey report indicates that malnutrition in the Region is very high especially among children under 5 years, with 36% being stunted and 27% underweight (Ghana Statistical Service *et al*., 2009). Studies on the relationship between climate change and health show that there is a correlation between weather variables and stunting (Grace *et al*., 2012; Jankowska *et al*., 2012). In fact, projections into the 2050s show that climate will increase the relative percentage of the severely stunted by 31-55%, thus reversing the benefits that would be derived from socio-economic development (IPCC, 2014b). This has serious health implications for this Region and its neighbours that have food security problems. A report from the Ghana Health Service also shows that malaria and malnutrition are the leading cause of anaemia in the Region (Ghana Health Service, 2012). These and many other health indicators make Ghana unlikely to meet its MDG (target 4) of reducing under 5 child and maternal mortality by two-third by 2015 (UNICEF, 2013). Thus with the projections from the IPCC, the future looks challenging for the healthcare in the Region. The health problems are particularly serious for the Region and its neighbours (Northern and Upper West) which have limited access to healthcare services.

However, the Regional Health Directorate with its partners are doing all they can to bring the situation under control. The activities being carried out include outreach programs aimed at sensitising the people on preventive measures, immunisations, vaccinations, distributions of insecticide-treated bed nets, deworming, nutritional treatments as well as other general services (Ghana Health Service, 2012). The CHPS compounds are being pursued, which serve as centres for first aid and treatment of minor ailment. The CHPS compounds are very important in the Region as health facilities are inadequate and settlements are dispersed. The presence of the compounds reduces the distances walked to a health facility greatly and hence reduces the rate of fatalities associated with some of the diseases. Similar to the agricultural sector, funding, inadequate staff and logistics are also the problems faced by the Regional Health Directorate in carrying out their activities. Many qualified health staff refuse postings to the Region, while others transfer out, thus leaving the staff to patient ratio very low (Ghana Health Service, 2012).

7.4.3 Water, housing and infrastructure sectors

As shown in Fig. 7.2, the water sector is vulnerable to extreme dry conditions though the vulnerability is minimal under current circumstances. However, the projections of the IPCC (2014b) for Africa suggest the vulnerability is likely to increase significantly in the future. This will cause greater reductions in crop and livestock production, as has already occurred in Sudan and parts of northern Nigeria (Nyong *et al*., 2005; Sanjak *et al*. 2005, both cited in AIACC, 2007). The extreme dry and hot conditions may result in water scarcity and the heating up of housing units, which have implications for the health of the people as illustrated above. The extreme wet conditions recharge the water system and have been predicted to increase (IPCC, 2014b).

While this is good for the water system, it is worrisome for the housing and infrastructural sectors as more and more infrastructure will find its way into valleys and close to rivers as a result of the alternate dry conditions. This is particularly a problem as the towns urbanise and villages consolidate into towns. Studies show that many African cities are already experiencing the consequences of floods (Douglas *et al*., 2008; Oteng-Ababio, 2011; UN-Habitat, 2011; Gyasi *et al*., 2014). Some rural-urban migrations in many countries, especially in the developing world, have been linked to the impact of climate change (Tacoli, 2009).Urbanisation due to rural-urban migration may create excessive demand for infrastructure in the towns and increase the number of people vulnerable to climate impacts (Seto, 2011).

The dwelling units and other infrastructure are also vulnerable to floods/heavy rainfall, especially the rural dwellings and the feeder roads, as these are built with weak materials. The analysis of the data showed that the combined effects of the extreme wet conditions and windstorms cause people to shift to the use of concrete and roofing sheets, although modernity and taste are also drivers of increasing use of these materials. The increasing use of these materials, as illustrated above, has health implications for the people. Floods/heavy rainfall and windstorms cause destruction to property, and displace and injure many people. The displaced have to seek refuge with neighbours or make do with limited school buildings as temporary shelters leading to the closure of such schools. This has been the case at Kubore where respondents indicated they usually move to live in the school building until the floods recede. This affects academic work, especially if the situation becomes protracted. With the infrastructural sector, the effects are more on the roads because those in the Region are largely untarred and therefore are eroded and in some cases, bridges and culverts are washed away. This leaves the roads in very bad condition and makes the delivery of goods and services, especially emergency services, difficult and expensive.

The water company, GIDA and their partners, particularly NGOs, have constructed a number of small reservoirs to store runoff for domestic and agricultural use aimed at minimising the impact of the dry conditions. There are also boreholes and wells sunk for similar purposes. NADMO and the NGOs provide relief services particularly to victims of floods/heavy rainfall who are displaced. They also provide early warning services to prepare those in flood prone areas to reduce the impact. As shown in the other sections, funding, inadequate staff and logistics were considered major barriers.

7.4.4 Overall vulnerability

As shown in Fig. 7.4, the Region is more vulnerable to droughts/high temperatures than floods/heavy rainfall. The agriculture sector, the major economic activity is more sensitive to droughts/high temperature than it is to floods/heavy rainfall. Also, the health and population sector seems more sensitive to droughts/high temperature than it is to floods/heavy rainfall. This is because droughts/high temperatures have more consequences on agricultural production and food security, water scarcity, loss of income and together with ill-health due to heat affect the general wellbeing of the people more so than floods/heavy rainfall. Floods/heavy rainfall also has high impacts on infrastructure (erosion of roads/silting of dams) and dwelling units, especially those along rivers or sited in flood prone areas. Although combining all these sectors shows that the entire Region is vulnerable to the hazards, some districts are more vulnerable to particular hazards than others. The Talensi, Nabdam, Kassena-Nankana West, and Garu-Tempane Districts have very high vulnerability scores than the others and even among this group of most highly vulnerable districts, there are variations with the Talensi District topping the vulnerability scores.

In the face of the impacts of these hazards, the adaptive capacities are fairly low across the sectors and districts. The low adaptive capacity was blamed on the over reliance on agriculture as a major economic activity which is largely rainfed and prone to losses when the rains do not fall as expected. This partly explains the high vulnerabilities in districts with fewer dams/dugouts because when the rains fail to come as expected, they do not have a strong alternative means to cope, that is, they have less water available for dry season gardening and watering of animals as compared to the their counterparts with more dams/dugouts. Besides the dams/dugouts, other adaptive capacity indicators in the form of social support (remittances, food aid, NGOs, emergency services, etc.), economic (income generating activities, employment, skills, etc.), financial support (banks, micro-credits) and infrastructure (roads, hospitals, schools, etc.) vary across the districts and help to explain the variation in vulnerabilities. Other factors that accounted for spatial variation in vulnerabilities were the variations in the susceptibilities as shown by the susceptibility maps in chapter 6. The variations in susceptibilities emanate from variations in exposure and sensitivities across space and sectors for the various hazards (see exposure and sensitivity sub-sections in chapter 4).

As shown in the analyses, the issues are cross-cutting with the effects of the hazards on one sector resulting in an impact on the other sectors. This means that there is the need for a multi-hazard/multi-sector approach to enable effective adaptation to the hazards and hence studies such as this are very relevant. Note that spatial mapping provides a “snapshot” spatial description of vulnerability at a particular point in time. But vulnerability is dynamic and as hazards of different types and magnitudes are encountered and socio-ecological conditions change, new vulnerability maps will be needed to reflect changes. Therefore, care must be taken when comparing the maps presented here to others produced from different data and methods.

From the research findings, the hazards of droughts/ high temperatures, floods/high rainfall, and windstorms are real and are increasing in frequency and magnitude in the Region. These changes are reported to be beyond the actions of poor people such as those in the Region (IPCC, 2007). This means that for the continued existence of the people and ecosystem on which they depend, there is the need for adaptation. This aspect is considered further in the next chapter.

Chapter 8 Adaptation to climatic hazards: Policy implication

8.1 Introduction

Since the recognition of climate change and its deleterious impacts globally, there have been calls (both internationally and nationally) to enact policies aimed at reducing impacts and vulnerabilities. At the international level, these policies have taken two-pronged approaches, focusing on mitigation and adaptation (Stringer *et al.*, 2009). However, this research will concentrate on adaptation since Africa contributes less to greenhouse gas emissions than many other parts of the world, but is the most sensitive and vulnerable continent to the impacts of climate change and therefore needs to adapt (Ludi *et al.*, 2012). Adaptation refers to process of deliberate change, often in response to, or anticipation of, multiple pressures and changes that affect people's lives (Nelson *et al.*, 2007, cited in Stringer *et al.*, 2010).The United Nations Framework Convention on Climate Change (UNFCCC), the leading treaty for international climate change, requires all Least Developed Countries (LDCs) to develop National Adaptation Plan of Actions (NAPAs) and National Climate Communication Response Strategies (NCCRS) (Stringer *et al.*, 2010). Though a number of countries have developed these NAPAs, implementation has been lacking, while integration with the development agendas of the countries is limited (IPCC, 2014b). Ghana is considered a low middle income country and is not required to prepare a NAPA. Instead the country initiated steps to promulgate a National Climate Change Policy (NCCP) in 2010. This will be discussed later.

At the national level, Ghana has sectoral policies that are formulated to direct development in the various sectors of the economy. Since Ghana is a signatory to most of the international agreements, these policies are formed in line with international considerations, especially the Millennium Development Goals (MDG) and UNFCCC. Ghana is operating a decentralised governance system and has policies being implemented at various levels by the different sectors of the economy. Thus, the objective of this chapter is to analyse the climate-related sectoral policies to identify the areas that can be synthesised and brought together in order to enhance adaptation in Ghana's savannah ecosystem. The policies were analysed using content analysis in line with the three stage process that have been agreed for qualitative document analysis (see Wesley, 2010). Here, an overview of the documents was first done to identify themes or focus areas that are climate related while making notes of these. The documents were then thoroughly reviewed and objectives, actions and outputs of identified themes or focus areas were quoted. The implementation of the actions of the policies and their outcomes were verified through focus group discussions with community members and in-depth interviews with institutional heads or their representatives. The focus group discussions and in-depth interviews also aided in identifying successes, failures, best practices, barriers , etc. for policy formulation or mainstreaming. These methodologies have been applied elsewhere to analyse the content of policy documents (e.g. WHO, 2009; Huang et al., 2010).Thus, the sections below provides a brief review of policies focusing on areas where the findings can be mainstreamed. However, before reviewing policies and mainstreaming, the barriers to adaptation to the climatic hazards in the area will be presented. This will set the context for reviewing the policies.

8.2 Barriers to adaptation

Although the impacts of climate change are heavy on the livelihoods of the people, they continue to adapt to the changing climate and its attendant hazards. In adapting, they meet a lot challenges which often hinder progress. The barriers that limit adaptation as identified in this study are summarised in Table 8.1. The subsequent discussion provides explanation in relation to each type of barrier.

Table 8.1 Barriers to adaptation to climatic hazards in the study area

Barriers	**Components**
Biophysical	Poor soil quality, water scarcity, land fragmentation, diseases
Financial	Poverty, lack of credit, delayed release of funds for projects
Cultural	Belief system, taste for traditional food crops, land management practices
Political	Political promises and interference, corruption, inadequate institutional capacity
Infrastructure	Limited irrigation facilities, inadequate health facilities, poor roads
Social	Limited access to land, land tenure system, limited knowhow, illiteracy, conflicts
Technological	Lack of agricultural inputs, lack of storage/processing facilities, inadequate early warning system, uncertainties in weather

Source (Based on field studies by Author)

Studies have shown that many Africans, especially small-scale farmers are not able to adapt to the changing climate due to a suite of overlapping barriers similar to those in Table 8.1 (see IPCC, 2014b). From the Table, it can be seen that a group of biophysical barriers hinder adaptation in the agriculture sector to climate change and variability. More than70% of respondents attributed low crop yield to low soil fertility, droughts resulting in water scarcity for crops, decreasing size of landholding as a result of population increase and land fragmentation, diseases and pest. These constraints have also been found to hinder adaptation of farmers in other parts of Ghana and in sub-Saharan Africa as a whole (Roncoli *et al.*, 2010; Mandleni and Anim, 2011; Nhemachena and Hassan, 2011; Nyanga *et al.*, 2011; Vincent *et al.*, 2011). Financial problems, manifested as poverty and lack of credit were reported by nearly all the respondents as limiting their ability to adapt. Low agricultural productivity, the main economic activity of the people, and lack of credit, to invest in farming due to lack of collateral often demanded by the financial institutions left the farmers in a vicious cycle of poverty and therefore unable to adapt meaningfully (Bryan *et al*., 2009). Indeed other studies on adaptation to climate change by African farmers have pointed out financial constraints as a limitation to adaptation (see Bryan *et al*., 2009; Kithiia, 2011).Government funding is also not adequate in most cases delayed leading delays in execution of interventions and increasing cost of adaptation (Stringer et al., 2010).

Cultural barriers such as the religious beliefs, food preference and land management practices have been documents to limit adaptation in Ghana and many part of sub-Saharan Africa (Mandleni and Anim, 2011; Jones, 2012; Mubaya *et al.* 2012). The participants in this study assigned the cause of climate change or the occurrence of climatic events to the act of God or their ancestors or smaller gods and therefore only pray or perform sacrifices to appease their ancestors and gods when the events manifest. Some communities even have rain gods where they perform sacrifices when droughts set in. To them, these events are limited to their communities. Even when prompted that these are occurring globally, they still held the belief that every society has gods or ancestors who are angry and are punishing the living with the harsh conditions. Most of the people (especially those in the rural communities) said they were so attached to eating food made and perform sacrifices with flour from traditional crops that it was difficult for them to change to planting introduced crops. However, participants mentioned that these values are gradually changing and they are eating foods made with these new crops. They attributed this adaptation to production losses of traditional crops due partly to the changing weather. Hence, many reported that they had adopted improved maize varieties as a major crop. Cultural barriers such as religious beliefs, food preference and land management practices have been documented to limit adaptation in Ghana and many part of sub-Saharan Africa (Mandleni and Anim, 2011; see IPCC, 2014b).

Limited access to land, insecure land tenure, limited knowhow and illiteracy are some social barriers that constrain adaptation in the area. The people said the land is no more adequate because family sizes have increased over the years. They therefore farm continuously on the small land while bringing marginal lands into cultivation. The land tenure system is insecure and this hinders adaptations that involve long-term investments in the land. In the focus group discussions, the participants said land has not been commercialised over the years because it is a communal property and is handed from generation to generation and no one is supposed to sell it. They however, do not have the means to maintain its quality for future generations. Politics and failed promises by politicians, according to the people, have contributed to making some people dependent on handouts or reluctant to embrace certain policies from certain governments which they do not support. A case that was mentioned to suffer from this issue this is the National Health Insurance Scheme (NHIS), possibly because it was fresh in people's memories. They also said change in government also hinders adaptation because of lack of continuity of projects or interventions when a government is changed. Corruption is also a major constraint as funds meant for interventions and adaptation are diverted for private gain (Ghana Integrity Initiative, 2011).Politicians also divert projects to their strong holds to satisfy their supporters, even if projects are not needed there. Although conflicts were not part of the focus of this study, they contribute to increased vulnerabilities. There are conflicts in the Region relating to land disputes and chieftaincy, sometimes resulting in vandalising properties and abandonment of projects. Some of these and many other barriers to adaptation have been documented (see IPCC, 2014b). With these barriers in mind, it is necessary to review the policies and suggest areas for mainstreaming.

8.3 Policy analysis

Ghana has a lot of policies in place to drive the development of the country. However, those that are specific to the findings of this research were reviewed to identify areas where such findings can be integrated to reduce vulnerability and enhance adaptation and sustainable development. The policies that were reviewed include the National Climate Change Policy (NCCP) (still going through the various stages of development as of 2014), Food and Agricultural Sector Development Policy (FASDEP II) (2007) and its programmes and actions plan called the Medium Term Agricultural Sector Investment Plan (METASIP) (2009), Ghana Land Use Policy (1999), Health Sector Policy (2007), Housing Policy (still going through the stages of development as of 2014) and Water Sector Policy (2007). These policies are selected because they relate to sectors that were identified as the most sensitive and vulnerable to climate change in the country. They were also selected because they are linked to food security and livelihood resilience and therefore need special attention if Ghana is to achieve successful adaptation to climate change. It must be noted that the review was not an attempt to find strengths and weaknesses of the policies but to identify areas where the findings of this research can be incorporated. The section below first considers sector policies and ends with the NCCP.

8.3.1 FASDEP II and METASIP

The food and agricultural sector development policy is a framework that guides development and interventions in the agriculture sector. The purpose of the policy is to "enhance the environment for all categories of farmers, while targeting the poor and risk-averse producers" (MOFA, 2007:1). One of the aims of this policy is to increase agricultural productivity to ensure food security, sustainable shared growth and poverty reduction. In order to meet the set purpose, the policy has several objectives linked to the Millennium

Development Goals (MOFA, 2007:22). However two objectives were picked for examination because they address the impacts of climate change indirectly (e.g. irrigation is targeted at increasing productivity and engaging farmers in dry season farming but it also addresses drought):

i. Food security and emergency preparedness
ii. Improve growth in incomes

Each of these objectives had different strategies and implementation procedures. The strategies are divided into components, actions and outputs. Actions that are relevant to this research are presented in Table 8.2. These actions are considered relevant because in the face of climate change impacts and the attendant hazardous events, there is the need for the use of technology to increase productivity, enhance food security and reduce poverty in the Region. From the field survey, the farmers indicated that they had moved towards the cultivation of short duration and improved maize varieties as their main crop and have recorded increases in production. The introduction of short duration varieties meant that this action has been rolled out. But this has the potential to turn the farming landscape of the Region to monoculture and also to expose farmers to other shocks such as pest and disease invasion. Olschewski *et al*. (2006) found that this kind of shift towards cultivating new species may alter the biodiversity and undermine some ecosystem services such as pollination in the area (cited in Stringer *et al*., 2009). Another study in India has highlighted the importance of crop diversification (Sarungbam and Prasad, 2011). It is therefore recommended that the crop research division of Council for Scientific and Industrial Research (CSIR) and other crop research institutions (both local and international) step up research into improving the millet and sorghum varieties as well as other crops so as to maintain diversity of crops.

Table 8.2 Selected outputs and actions of objectives 1 and 2

Objective: Food security and emergency preparedness		
Component	**Output**	**Action**
Productivity improvement	Improved technologies adopted by smallholder farmers and yields of maize, rice, sorghum, cassava and yam increased by 50% and cowpea by 25% by 2015.	Introduce improved crop varieties (high yielding, short duration, disease and pest resistance, and nutrient fortified).
		Increase access to fertilizer
		Seed/planting material
	Production of poultry (including guinea fowl) increased by 20% and small ruminants and pigs by 25% by 2015 through adoption of improved technologies	Introduce improved livestock breeds
Support for off-farm/ alternative livelihood activities	Five percent of people falling below extreme poverty line supported to engage in off-farm livelihood alternatives by 2015	Promote off-farm activities with particular focus to supporting establishment of agro processing Micro and Small Enterprises (MSEs), and targeting women and the youth
		Introduce targeted grants and subsidies on inputs to poor farmers to improve farm level production and marketing activities
Irrigation and water management	Irrigation schemes' productivity increased by 25% and intensification by 50% by 2012	Rehabilitate Vea and Tono dams
	22,590 ha of micro irrigation schemes developed by 2015 and 2,385 ha of small scale irrigation schemes developed by 2010 to benefit 50,000 households	Identify sites in various river flood plains for micro irrigation systems
		Facilitate installation and establishment of pump irrigation systems
		Facilitate the formation of water users' associations at the irrigation sites.
		Promote use of existing small community and small scale dams
		Identify suitable areas for the construction of community small scale irrigation dams and establish small scale furrow irrigation systems
Objective: Increased growth in incomes		
Promotion of cash crop, livestock and fisheries production for income in all ecological zones	Income from livestock rearing by men and women increased by 10% and 25% respectively by 2015	Identify areas with acute problems of water for livestock and construct water points (at least 50 per year starting from 2009)
		Promote communal grazing lands
		Facilitate and support establishment of pastures and fodder crops by farmers

Source: MOFA (2009)

During the focus group discussions, farmers were asked if they have any history of transplanting and this was affirmed for late millet, rice and sorghum. Thus, as a measure against dry spells, farmers could be educated and sensitised to grow these crops in nurseries during the early part of the rainy season and transplant them when the rains begin to normalise. Irrigation has long been used but has been limited to the cultivation of rice and vegetables. This has largely been done by damming water courses to provide water. However, with projected climate changes, there is the likelihood that droughts will increase and that will mean a decrease in runoff to store in the constructed reservoirs for irrigation, as well as increased evaporation. Groundwater is less affected by these hazards and could be used to adapt to droughts. Also, groundwater use does not require land to create a reservoir and therefore makes land which is becoming scarce available for farming or other livelihood activities. It is therefore recommended that groundwater, particularly in areas with high groundwater potential, be considered to augment the current scheme. These groundwater points could be fitted with pumps powered by solar energy to transfer the water to the fields. Some farmers involved in the research are using groundwater and found it to be convenient and therefore its use could be upscaled. Flood recession agriculture which was mentioned by some farmers at Kubore should be considered and encouraged wherever it is favourable as an option for adaptation to floods. Grouping farmers and providing them with inputs in advance, allowing them to pay after harvest as adopted by BESSFA rural bank could be studied to see if it is sustainable. If it is found to be sustainable, a similar approach could be encouraged to be adopted by other banks and by the government's small loans schemes. Insurance in the agriculture sector in Ghana is a relatively new concept (Stutley, 2010). Although it is not captured in the agriculture sector policy, it should be encouraged as it will protect farmers against losses (Stutley, 2010).

The guinea fowl (*Numida meleagris galeatus*) has been identified as a drought resistant bird and therefore its promotion in the Region offers hope to increase productivity and income (Teye and Adam, 2000; Gono *et al*., 2013). Guinea fowl farming will therefore increase the financial capacity of the people to adapt the hazards. But farmers indicated that the keets (chicks) die when there is excessive heat. High mortality of the keets and attacks by predators among others were found as major barriers to guinea fowl production in the savannah ecosystem (Teye and Adam, 2000). It is therefore necessary for the agriculturists to find a way of avoiding deaths at the early stages of the bird's life cycle and to educate farmers on that. For example, the extension agents and NGOs could sensitise farmers to build huts using mud and thatch to provide shade, moderate temperatures and to protect the keets from predators. The ground of the huts could be sprinkled with water on a daily basis to moderate temperature.

With decreasing quantity and quality of grazing lands, farmers could be sensitised on keeping animals on an intensive basis and cultivating fodder to feed the animals. They could also be educated on keeping more animals such as pigs, which are less dependent on fodder in order to increase their incomes. Integration of small ruminant animals into crop farming, especially in highly vulnerable districts, should be encouraged as this has been successful in neighbouring Burkina Faso (Amankwa *et al*., 2012). Thus, Burkina's model could be adopted, though commercialisation of small ruminant production is not seen as a viable option in northern Ghana due to the cultural value systems (Amankwa *et al*., 2012). However, studies on constraints to small ruminant production in Ghana and Nigeria identified a lack of extension services, inadequate and high cost of drugs, preference for crop production, inadequate pasture as well as lack of credit as constraints (Aphunu, *et al*., 2011; Amankwa, *et al*.,2012). These lessons should guide policy should the recommendations be taken up, such that effort are met with greater success.

The support for off-farm activities and other income generating activities are meant to diversify the production base, increase farmers' incomes and reduce poverty in the Region. So aside from the traditional processing and trading of agricultural produce, government could promote investment in viable opportunities such as the leather industry, clay for bricks and rocks for tiles, etc. This will increase employment opportunities and reduce the dependency on agriculture as a main economic activity. Some of the interventions need to be implemented as soon as practicable because delay in implementation may be counterproductive and increase vulnerabilities (Stringer *et al*., 2009). Remittances from relatives were used in adapting to these hazards. They have been found as useful adaptation strategies in local communities elsewhere (Dixon *et al*., 2014) and therefore ways of enhancing them such as bringing mobile money transfer closer to the communities could be encouraged.

Implementing these interventions across board in the Region could enhance adaptive capacities and reduce susceptibilities to the hazards, thereby reducing vulnerability. However, the districts with high to extreme vulnerabilities need special focus. In these districts, the major reason for the high vulnerabilities is the high crop sensitivities to drought. The soils have low water holding capacities and are always exposed to the sun at the early stages of growing period. Therefore, prolonged droughts and high temperatures result in high evaporation of water from the soil resulting in low moisture available to the plants. Thus, in addition to providing drought and heat tolerant crops, farmers should be sensitised not to burn crop residue on farms. This, in addition to other soil moisture management practices, should be encouraged. For example, residue retention has been found to contribute to increased crop yield under both rainfed and irrigated systems in Mexico (Govaerts *et al*., 2008). In the agriculture sector, priority areas for policy to focus on in the highly vulnerable districts are summarised in Table 8.3. In addition, all districts need to build the capacity of their farmers on soil moisture conservation practices through extension services. This requires adequate investment. Although these nine districts (Table 8.3) are selected, through this research, for priority setting by their respective district assemblies as well as central government, the other districts could implement these interventions too, as all are vulnerable to droughts/high temperatures in this sector.

Table 8.3 Areas for policy consideration for adaptation in the agriculture sector

District	**Intervention focus**
Talensi	Provision of irrigation facilities, investment in livestock and poultry, increase mining and quarrying activities to provide alternative employment, transplanting crops
Nabdam	Provision of irrigation facilities, investment in livestock and poultry, increase mining activities to provide alternative employment, transplanting crops
Bolgatanga Municipal	Provision of irrigation facilities, investment in livestock and poultry, transplanting crops, straw basketry,
Kassena-Nankana East	Investment in livestock and poultry, straw basketry, research into the length a fresh tomato can stay under cold conditions before going bad and invest in such facilities
Kassena-Nankana West	Provision of irrigation facilities, investment in livestock and poultry, mainstreaming tourism, transplanting crops
Binduri	Investment in livestock and poultry, transplanting crops
Bawku Municipal	Investment in livestock and poultry, transplanting crops, investment in the tanning industry
Garu-Tempane	Provision of irrigation facilities, investment in livestock and poultry, transplanting crops
Pusiga	Investment in livestock and poultry, transplanting crops

Source (Based on field studies by Author)

The eastern part of the Talensi District has high groundwater recharge and large tracts of vacant land which can be used for irrigation purposes. This is because irrigation is seen as key for spurring agricultural growth in sub-Saharan Africa in the face of climate change (e.g. Dillon, 2011). However, crop suitability analysis/research would have to be performed to select appropriate crops for the area. The western part of the district can adopt both groundwater and dam/dugout irrigation just as all other districts. Several districts in savannah ecosystem have similar attributes to the districts in the Region and therefore need to consider some of these options for adaptation to climatic hazards. Construction of dams and proper land management practices will reduce runoff and hence reduce impacts of floods.

8.3.2 Health policy

The health sector policy was formulated in 2007. It regards the human being as a tripartite being made up of the body, mind and spirit and that the wellbeing of human requires fostering harmony among this tripartite being (MOH, 2007). This is derived from the WHO definition of health as the state of complete physical, mental and social wellbeing and not just the absence of infirmity or disease (cited in MOH, 2007). A key element of this policy is the recognition that good health plays a critical role in the socio-economic development of the country and based on this understanding, it has developed some key shifts in healthcare delivery in the country. Among the paradigm shifts, "health improves productivity and creates wealth" (MOH, 2007:32) is in line with the interest of this research. This is because a healthy population will engage in their livelihood activities productively and spend resources less on treatment. This will result in increased incomes and hence increased financial capacity to adapt to the hazards.

The main goal of the health sector is to have a healthy and productive population that reproduces itself safely. It will achieve this goal by the following objectives (MOH, 2007:33):

i) Ensuring that people live long, healthy and productive lives and reproduce without an increased risk of injury or death

ii) Reducing the excessive risk of burden of morbidity, mortality and disability, especially among the poor and marginalised groups

iii) Reducing inequalities in access to health, populations and nutrition services and health outcomes

These objectives, if met, will go a long way to improve the welfare of the people of the Upper East Region who are largely (90%) poor and have limited access to health facilities. These objectives are particularly important as there is an increasing trend of health risk related to climatic hazards. Malaria and meningitis (CSM) are among the top 10 killer diseases in the country (MOH, 2007).These climate related diseases are increasing due to increasing temperature, floods and heavy and erratic rainfall (Ghana Health Service, 2012). Injuries from climate related hazards and high malnutrition are also recorded (NADMO, 2011; Ghana Statistical Service *et al*., 2009). To accomplish these objectives, some strategies were developed to address current health system constraints. These include improvements to supply chain management and monitoring, expansion of the CHPS compounds, reinforcement of pro-poor financing mechanisms (including free or subsidised care for certain conditions as well as the National Health Insurance Scheme) and refined human resource policies (MOH, 2010).

In this sector, with the exception of Bawku West District, which was resilient, all districts show low to high vulnerability. Those districts that were highly vulnerable (i.e. Kassena-Nankana West, Builsa South and North, Talensi, Nabdam, Binduri and Garu-Tempane) had high cases of malaria and/or CSM and low healthcare infrastructure than the low vulnerability and resilient districts. These highly vulnerable districts need to improve their healthcare infrastructure and general primary healthcare in the short to medium term by adopting mobile healthcare delivery services, vaccinations, distribution of treated insecticide nets, etc. while investing in healthcare infrastructure and training of personnel in the long term. The low vulnerability districts (i.e.

Kassena-Nankana East, Bolgatanga, Bongo, Bawku and Pusiga) had high cases of malaria and CSM and should therefore invest in the short-term measures as above while improving infrastructure. In all districts, there is the need for the formation of a taskforce within the healthcare system to increase campaigns and awareness creation on the use of treated insecticide nets and trees and shade, especially during the hot periods to reduce exposure and contraction of CSM. This recommendation is currently being encouraged to reduce risk of heatwaves in the UK (NHS Sustainable Development Unit, undated).

The Region generally has low adaptive capacity due to inadequate staffing, infrastructure and logistics. Its settlements are also largely dispersed, which means some people will have to walk for a long distance to get to a health facility to receive treatment. Thus to ensure equitable distribution of health services to the people, the CHPS compounds concept should be pursued vigorously and made more dense in order to minimise the distance people will have to walk under the scourging sun to health facilities to receive treatment. These CHPS compounds should be equipped to properly diagnose and treat the patients and in cases where the situation is critical, they can then call the ambulance service to pick the patient up for the hospitals. This will help to reduce fatalities and improve the conditions of the people, thus enabling them to engage in their livelihoods activities productively.

Some people indicated they could not afford the upfront payment of the premium of the health insurance. Payment of premiums by installments, in cash or kind or at harvest time have been successfully implemented in Uganda, Ethiopia, India and Senegal respectively (Morestin and Ridde, 2009) and could be adopted for the people of this area. NGOs and other philanthropists could also be encouraged to assist those who cannot genuinely pay for the premium. The CHPS compounds should have a nutritional centre with trained staff to counsel people who visit the centre and periodically organise outreach programs to educate them on the need to have good nutrition, especially for children.

8.3.3 Land use and housing policies

Natural resources and the processes of their development and use have varying consequences on the environment. This is more so in the face of increasing climate variability, which subsequently affects the use and productivity of land (Gyasi *et al*, 2006). For example, continuous low rainfall or droughts may make people settle or undertake other livelihood activities in flood prone areas. When the rains fall heavily, those livelihood activities are flooded and destroyed. In order to manage the use of land properly, the Government of Ghana instituted the land use policy. The main objective of the policy is to ensure the judicious use of the nation's land and all its natural resources by all sections of the Ghanaian society in support of various socio-economic activities undertaken in accordance with sustainable resource management principles and in maintaining viable ecosystems (Ministry of Lands and Forestry, 1999). Several institutions were thus mandated to oversee the allocation and use of the land and its resources. The concerned institutions entrusted to oversee residential development include Town and Country Planning Department, Lands Commission, the Traditional Authorities and Metropolitan, Municipal and District Assemblies (MMDAs).

The situation as described above is the result of the increasing need for shelter by the growing population, particularly in the urban centres. The Government of Ghana, recognising this need, instituted the housing policy and carried out reforms in the 1990s with the hope of increasing the housing stock (Arku, 2009). These reforms attracted a lot of investments in the formal sector, however, the informal sector remains the dominant producer of houses, accounting for 65–70 percent of all new housing units (Arku, 2009). About 90 percent of housing in urban Ghana can be classified as informal as they are built without local authority control (UN-Habitat, 2011). There are legislation and regulations covering all the main sectors involved in housing provision and control but many of them impose significant transaction costs and unnecessary delays (UN-Habitat, 2011).

The in-depth interviews indicate lack of resources to perform their mandates resulting in the development of residential facilities in areas without planning schemes or unapproved areas. The focus group discussions also identified poverty, corruption and bureaucracy as the main problems. According to UN-Habitat (2011), building codes and lack of knowledgeable artisans, material standards and social acceptability also militate against the use of traditional building materials. As a result, buildings are constructed without permits or in unapproved places such as swamps, close to/on river banks, water ways etc., especially in the urban/peri-urban neighbourhoods with poor drainage systems exacerbating the flooding problem when it rains (UN-Habitat, 2011). This could be attributed to a lack of research and education into the health implications of the different building materials, particularly for northern Ghana where temperatures are extremely high. The focus group discussions on these issues identified poverty, corruption and bureaucracy as the main problems. Hence, buildings are springing up at a fast rate in swamps, close to/on river banks, water ways etc., especially in the urban/peri-urban neighbourhoods with no proper drainage systems exacerbating the flooding problem when it rains (UN-Habitat, 2011).

Lack of information for planning schemes for the urban areas could be resolved by the acquisition and use of high resolution satellite image to serve as base maps. Government should also enforce the buffer zone around water courses by acquiring lands within the buffer and turning them into forest plantations which could be used as recreational areas in the dry season. Other flood prone areas should be acquired with the necessary compensation paid to land owners and used for irrigation either by flood recession or sprinkler irrigation using groundwater. The bureaucratic bottlenecks and delays in approving building plans should be reduced to ensure buildings are built according to building codes. On the part of building materials, research into materials conducive for the weather to help people adapt to the changing and warming climate should be undertaken. Therefore there is the need for research into this area and better options made available to the people to help them adapt to the changing and warming climate. The technical and vocational institutions, particularly those in the Region, should train students on moulding and building with local materials such as mud bricks, which are shown to moderate temperature (Donohue, 2010).

8.3.4 Water policy

Water is central to many human activities including those mentioned above. For example, water is needed for food production and consumption, hygiene and good health, building of structures and many other industrial uses. The water policy has focus areas on water resource management, access to potable water, climate change and water for food security. Water for food security focus area is akin to the water for agricultural production which has been dealt with under the agriculture sector policy and therefore will not be repeated here. The remaining three focus areas, water resource management, access to potable water and climate change, are essential to the research findings especially for adaptation to climate change.

The objectives of focus area 1 (Integrated Water Resource Management (IWRM)) are to achieve sustainable water resource management and ensure equitable and sustainable exploitation, utilisation and management of water resources while maintaining biodiversity and quality of the environment for future generations (MWRWH, 2007:13). To meet the set objectives, a number of policy measures and/or actions have been drawn up. One such actions seeks to conserve water resources through the use of cleaner and efficient technologies, effective waste management and sound land management and agricultural practices by promoting partnerships among stakeholders (MWRWH, 2007). This is particularly important considering that the climate is becoming warmer and droughts/floods frequency and severity are also projected to increase. The general objective of focus area 2 (Access to water) is to improve access to potable water to all the people without discrimination. To achieve this objective, policy measures and/or actions have been crafted. Of particular interest is the action on improving efficiency in the production and distribution of water through effective and improved operations and management and pricing mechanisms that take the poor and vulnerable into account. This is particularly important as access to potable water (especially by the poor and vulnerable groups who form the majority of the population of the Region) is essential for healthy life.

Regarding the focus area on climate change, its objective is to minimise the effect of climate variability and change and to mitigate likely damage to be caused by floods and droughts. Among the number of measures and/or actions set out to achieve this objective are constructing flood protection structures at appropriate locations, establishing and enforcing buffer zones along rivers and ensuring that rain water harvesting is incorporated into building codes.

The discussions with community members indicate that they have access to portable water through the use boreholes and wells. They also do not pay for the water. Data from Community Water and Sanitation Agency (CWSA) also indicate almost all communities are fitted with more than one borehole or well to reduce crowding and distance walked to water points. To fulfill the objectives of the focus areas, it is recommended that the Ghana Water Company and CWSA collaborate with the institutions in charge of the land use policy to ensure effective implementation of the buffer zones. Observations from the use of a sprinkler irrigation scheme in the Keta area (Volta Region of Ghana) show that the system is effective in managing water for agricultural purposes. It is therefore necessary for this to be introduced, especially in areas with sufficient groundwater, to support all year round irrigation. Rainwater harvesting which has not been exploited in the Region, should be encouraged and/or introduced as it could help manage flash floods and also store water for irrigation and domestic chores, particularly in urban/peri-urban areas. Harvested rainwater would be a useful additional water source in drought periods too. Spatially, with the exception of Kassena-Nankana East and Bolgatanga Municipal which are resilient in the water sector, the rest have low to high vulnerability. Their vulnerability is largely due to inadequate number of dams/dugouts for irrigation and watering of animals. Also there is lack of electricity to pump water to the residents in the big towns. These districts exhibited similar vulnerabilities in the agriculture sector and thus, the construction of dams will help reduce the vulnerabilities.

8.3.5 The National Climate Change Policy (NCCP)

The NCCP is more or less a cross-sectoral policy as it has captured all sectors in its framework. The good thing in the NCCP, which is missing in the other sector policies, is that it identifies sectors that a focus area fits and assigns the responsibility of implementation to the Ministry, Department or Agency responsible for that sector. This avoids the duplication of projects and reduces unnecessary funding. Areas related to the sectors discussed above will therefore not be covered here. Emphasis is instead laid on the disaster preparedness and response focus area, with the following programs to be implemented:

i. Develop climate resilient infrastructures
ii. Early warning mechanisms
iii. Public education and adaption skills
iv. Rapid response and disaster management

These programs are selected because they aim to increase the resilience of communities to adapt to the changing climate. For example, climate change and associated hazards, particularly floods, windstorms and high temperatures, cause damage to critical infrastructure such as roads, schools, hospitals, electricity poles/pylons, water systems etc. as well as personal properties of the people. Aspects of these have already been considered in the sector policies. It is recommended that the construction of infrastructure should include climate change resilient technologies at their design stage so that they can withstand the adverse conditions. Diameters of culverts need to be increased and poles/pylons anchored well. High temperatures increase energy demand, which is irregular in Ghana and therefore there is the need to construct structures with materials that can regulate temperatures to reduce reliance on energy for cooling. Mobile phones were observed during the field work to becoming more common than the radio and voice mails in the local languages and text messages should be used to augment the current early warning system. Similar systems have been developed and implemented elsewhere (Windarto, 2010; Uddin and Awal, 2013). The help or assistance given by family members or neighbours should be encouraged through public education so that they continue to provide support for each other. This is waning because of western values and capitalism which is gaining roots in communities, thus making people become more individualistic.

Family members or neighbours are often the first to help following a hazard, particularly in the rural communities where their aid in terms of food and temporary accommodation is urgently needed. Rapid response teams and first responder volunteers need to be formed in the communities to offer assistance to the hard hit and the vulnerable.

8.3.6 Autonomous adaptation

The people have over the years adapted to climate and environmental change through social networks, crop and livelihood diversification, and migration and/or remittances (World Bank, 2010; UNISDR, 2011).Social networks become very useful when people move into new areas or are affected by the hazards (Stringer*et al*., 2010; UNISDR, 2011) whereas livelihood diversification serves as a buffer to shocks and stresses from climatic hazards (Mkwambisi, 2009). Remittances from relatives living outside the communities are also useful adaptation strategies in the local communities (Dixon *et al*., 2014). Some of these adaptation strategies have been captured in the NCCP and should therefore be implemented to enhance adaptive capacities. These autonomous local adaptation strategies need integration into adaptation policy and planning as research shows that support to local-level adaptation is best achieved by starting with existing local adaptive capacity, and incorporating and building upon present coping strategies and norms, including indigenous practices (Huq, 2011, cited in IPCC, 2014b; Dixon *et al*., 2014; Bermann *et al*., 2012).

Another adaptation strategy that emerged from the research is flood recession agriculture which should be given research attention particularly in the Binduri, Talensi, Garu-Tempane and Bawku West districts which border the White Volta River and the Builsa districts which border the Sisili River, a tributary of the White Volta. The early warning system currently in place needs to improve. It is suggested that each of the sectors discussed above set up an early warning unit within it to monitor and predict a hazard and its consequences and warn the people as well as seek assistance to control the outbreak or disaster. This system was observed to be operating in the agriculture and health sectors, though not institutionalised. These early warning units could be coordinated by the National Disaster Management Organisation (NADMO) with assistance from the NGOs and development partners at the Regional level. Early warning systems are reported to be gaining grounds in Africa and therefore need to operate within an integrated policy framework (Vincent *et al.*, 2011; Funk *et al.*, 2012).

8.3.7 Critical areas for investment

Adapting to climate change require resources, especially financial resources (Antwi-Agyei *et al*., 2013). But as indicated above, one of the financial barriers to adaptation is poverty. Poor households have limited assets that they can draw upon to adapt to climate change (Dasgupta and Baschieri, 2010, cited in Antwi-Agyei *et al*., 2013). Thus, measures to make poor rural households to move out of poverty will help in avoiding and managing risk (IFAD, 2010). Many studies have concluded that the achievement of poverty reduction in poorer communities or countries is linked to growth in agriculture since these people lack skills and have fewer assets to rely on (e.g. Grewal, *et al*., 2012; Dorosh and Mellor, 2013). Agriculture and the other sectors discussed above are interlinked and together influence poverty (IFAD, 2010). However, for the agriculture sector to spur rural growth, reduce poverty and enhance adaptation in the Region, it has to be transformed through investments by government and the private sector (DFID, 2005).

Investments will have to be all inclusive if meaningful adaptation and poverty reduction outcomes are to be achieved. They will also need to be targeted, taking into account, the district's peculiarities and community needs, and should involve a participatory process to identify local needs in the face of climate change. Indeed, top-down processes often are unsuccessful due to lack of local ownership of interventions (Dyer *et al*., 2014). The important areas that require investment in the agriculture and other sectors which are critical for poverty reduction and to enhance adaptive capacity are summarised in Table 8.4.These priority areas in adapting to climate change and climatic hazards include both short and long term interventions. The often short-term nature of policy and other interventions, especially if they favour economic growth and modernisation over resilience and human security, may themselves act as stressors or allow people to only react to short-term climate variability (see IPCC, 2014b).

Table 8.4 Areas for investments by government and partners to enhance adaptive capacity

Priority Area	**Specific areas requiring improvements**
Infrastructure	Provision of irrigation and health facilities, improvement of roads,
Extension and outreach	Agricultural extension services, healthcare sensitisation and vaccination, training and recruitment of staff, provision of logistics
Livelihood diversification and education	Skills training, investment in alternative income generating activities, credit facilities, formal education,
Early warning systems	Set up early warning units, disease surveillance, food security monitoring, disaster risk monitoring and communication,
Research	Crop and land suitability, regular research on vulnerabilities and adaptation options to climate change, evaluation and monitoring, flood recession agriculture, transplanting, role of remittance

Source (Based on field studies by Author)

Thus, investing in both short/long-term adaptation options will most likely lead to sustainable development. Timely and adequate investment in these areas will enable adaptation to hazards by increasing agricultural productivity, reduce ill-health, and aid in reducing vulnerability (Dorosh and Mellor, 2013). Increased agricultural productivity will also mean more income and food security, especially for the poor, and hence poverty reduction (IFAD, 2010). Investment in off-farm activities such as the granite for tile production, clay deposits for ceramics production, mining, etc. will create alternative employment, increase incomes and diversify the Region's economy to the withstand shocks and lead to sustainable development (IFAD, 2010).

8.4 Summary

The objective of the chapter was to propose mainstreaming of the key findings into policies for implementation at the local level. This was achieved by analysing the barriers and then reviewing policies of the various sectors in order to identify recommendations that can help to enhance the adaptive capacity of populations in the Region. It is recognised that there are several barriers to adaptation in the Region. Appropriate policy recommendations were made recognising the need for adaption. Therefore, government and local authorities as well NGOs should consider adopting them for action, especially areas identified for investment. Investing in these areas will aid the people to adapt to the changing climate.

Chapter 9 Overall summary and conclusion

9.1 Summary

The aim of this research was to map vulnerability of the savannah ecosystem to climatic hazards using the Upper East Region as a case study. The aim was divided into specific objectives and the results from analysing these objectives are summarised in the following sub-sections.

9.1.1 Climate variability and change

Objective one of the research was set to study the trend of the climate over the last 3 decades so as to identify the hazards occurring and their impacts on the ecosystem and the livelihoods of the people. It was found that the incidence of drought, high temperatures, heavy rainfall, floods and windstorms are a common occurrence in the Region. This was amply demonstrated by the SPI values as well as local perceptions and records. The occurrence of these events has been reported to be linked to climate change (IPCC, 2014b). These events occur at varying degrees of frequencies and magnitudes spatially, even at the local level. Within the 25 years used to analyse the SPI data, droughts have occurred 9times at Binduri, 10 at Manga, 12 at Navrongo and 13 times in Vea. The number of times that drought events occurred at each station seems the same before and after 2000 but magnitudes were higher after 2000 than before 2000.Frequency and intensity of dry spells were greater after 2000 than before 2000.The floods/heavy rainfall events have occurred about 7 times in all stations but have increased in frequency and impact after 2000 compared with before 2000. This is largely due to spilling of dams from Burkina Faso and an increasing tendency to locate human activities in flood prone areas. The events occur in different years/seasons and times of the season at each station though some have occurred in the same season/time throughout the time series. Temperatures continue to rise in consonance with the findings of fifth report of the IPCC, and rainfall varies in intensity and duration. It was also found that the intensity and frequency of the winds have increased over the last 10 years.

These hazards are predicted to increase in the next 5 decades and will have great implications for the livelihoods of the people and the ecosystem on which they depend for survival (IPCC, 2014b).Even though studies have shown that the decade after 2000 was wetter than the decade before 2000 (e.g. Logah *et al*.**,** 2013), the occurrence of droughts and dry spells were equally high, an indication that the rainfall events were concentrated in periods of just a few months. Therefore, the trend emerging is that of increasing incidence of the hazards with greater consequences for livelihoods. The livelihoods activities of the people were highly climate sensitive. The impacts of the hazards were substantial for agriculture, population, health, water and infrastructure. The occurrence of the dry and wet conditions thus varies both temporally and spatially. These are similar to findings to other studies in sub-Sahara Africa and elsewhere (see IPCC, 2014b for such studies).

9.1.2 Adaptive capacity and vulnerability

Objectives 2 and 3 studied the adaptive capacities of the people and determined the sectoral/spatial vulnerabilities to the hazards identified in objective 1. Adaptive capacity in the Region was found to be low. The adaptive measures found include dry season irrigation, crop diversification, extension and outreach programmes, migration/remittances, flood recession agriculture, food aid, sitting under trees and shade, use of modern building materials, integration of animals into crop farming, vaccination, among others. Capacities were nevertheless low due largely to poverty, cultural values, illiteracy, poor infrastructure, poor institutional capacity and lack of financial capital.

The variation in the occurrence of the hazards as well as sensitivities and adaptive capacities produced variation in vulnerabilities across sectors and districts and among hazards. Five major sectors: agriculture, health, water, housing and roads were found to be vulnerable to the hazards to different extents. The agriculture sector is the most vulnerable. It is highly vulnerable to droughts and high temperatures and highly vulnerable to floods and high rainfall. The net effect of climate hazards in the agriculture sector is crop production losses leading to loss of income and food shortage in the Region. This partly explains the high and persistent incidence of poverty in the Region (WFP, 2012, Ghana Statistical Service *et al*., 2009). The Region has seen a lot of food crises in recent past with highest food aid received in 2007 after the flood incident (Reliefweb, 2007). The districts with the highest (negative) vulnerability scores in the agriculture sector are Kassena-Nankana West, Talensi, Nabdam, and Garu-Tempane. Food shortages resulting from local production makes the people resort to coping behaviours that increase malnutrition. For example, from the findings in this research and also from the WFP (2012) report, one of the coping strategies adopted by the people is reduce food intake, both in quantity and number of times in a day with some even going hungry for days. This practice may result in malnutrition and this could partly explain the persistent high malnutrition in the Region (UNICEF, 2013).

Besides malnutrition resulting from agricultural failure, other health problems emanating from the incidence of these hazards include malaria and CSM. The research found that CSM, headache and general body pains are the most common ailments the residents complain of due to increases in temperature. The Ghana Health Service (2012) report also shows an increase in CSM cases in health facilities between 2006 and 2012, and most of these occur in the dry season between November and March. The districts with the highest (negative) vulnerability scores in this sector include Kassena-Nankana West, Builsa North and South, Talensi, Nabdam, Binduri and Garu-Tempane. Although these diseases and sicknesses affect society in general, the vulnerable, especially pregnant women and children, are most affected because of low/decreased immunity (WHO, 2013). The increasing incidence of the climate related ailments increases the health burden of the people and the Region as a whole, as more funds are channelled to the acquisition of medicines for treatment. The indirect health impact is a reduction in labour output and incomes, thus perpetuating poverty.

The housing sector is not also spared from the brunt of climatic hazards. Traditionally, the Region's housing units comprised mud bricks/earth material for the walls and thatch or mud for the roof. These buildings materials provided insulation on the effects of temperature to the dwellers and reduced health risks related to heat. It has been found that thatch in Devon, an English county, keeps the temperature of the rooms warm in winter and cool in summer (Devon City Council, 2003). Thatch in northern Ghana provides a similar insulation effect, keeping the rooms warm during the cold harmattan winds between November and February and cool during the hot period between March and May. Due to the increasing incidence of the climatic hazards coupled with population pressure and bushfires, thatch has become scarce. The jute used to bind the thatch together is weakened or rots after being subjected to intense rainfall and windstorms. The thatch therefore gets ripped off easily by the winds. The earth buildings also collapse during the heavy rains and floods. The result of these effects, coupled with modernisation, has caused the people to start to shift away from the traditional building materials towards concrete and metal roofing sheets.

Though these modern materials are relatively more durable than the earth and thatch, they transfer heat from the sun directly into the rooms and trap it in for long periods. This makes the rooms very hot to stay in, especially during hot periods, and increases the risk of getting CSM and other heat related ailments. This is a potential factor for the increase in reported cases of CSM in the Region. However, access to electricity (which is needed to power the cooling or ventilating systems such as air conditioners and fans) is poor, with only 24% of households having access to electricity, with less than 4% of these households being in the rural areas.

The water and road sectors are less vulnerable to climatic hazards than the agriculture, health and housing sectors. Because the roads are largely feeder roads, they are prone to erosion and waterlogging around the slopes and valleys respectively. Road also get rippled by the tyres of cars when they get soaked by heavy rains. This makes travelling on the roads uncomfortable. Thus, with the construction of culverts to channel water away and investment in re-gravelling, the roads are able to serve the purpose of transporting goods and services between the communities. However, it must be mentioned that sometimes these culverts are washed away and making the road unusable. The water sector is more vulnerable to droughts/high temperatures than floods. A discussion with community members indicated that very few groundwater points are within flood prone areas and therefore pollution due to flood will be minimal. The major effects on the water sector are the high evapotranspiration and siltation of surface water bodies (Obuobie, 2008; Liebe *et al.*, undated). Siltation reduces the storage capacity of water bodies making them to store less water than was designed to store. This means that the excess water from the catchment of the reservoir will have to be spilled away.

The findings of this study are similar to findings of other studies in Ghana relating to vulnerabilities to climatic events. For example studies by Antwi-Agyei *et al*. (2012) and Aniah *et al*. (2013) found agriculture (both crops and animals) in the Guinea Savannah zone to be highly vulnerable to droughts. Other studies in sub-Sahara Africa document similar findings (e.g. Dixon *et al*., 2014; Burke *et al*., 2013; Callo-Concha, *et al.*, 2012; see also IPCC, 2014b for other studies). Similarly, the adaptation strategies found in the study share common ground with those documented in other studies (e.g. Bryan *et al*., 2009; Ludi *et al*., 2012; Nhemachena and Hassan, 2011). Many districts in the savannah ecosystem of Ghana and in many parts of the sub-region have similar characteristics and therefore will exhibit similar vulnerabilities. The recommendations made can thus be applied in such areas, making them applicable beyond the specific area of study.

9.1.3 Conceptual framework

The questions of vulnerability have always been about the vulnerability of 'whom to what', and about 'what is' driving vulnerability. Scientists, in trying to answer these questions have come out with several definitions, theories and conceptual frameworks, and yet none satisfactorily measures or explains vulnerability due to theoretical limitations and variation in backgrounds (Lei *et al*. 2014; Noy and Vu, 2011; Cuevas, 2010). The multiplicity of these terms have resulted in confusion with some arguing that vulnerability is meaningless unless it is contextualised (Schoon, 2005). In this study, a new framework was constructed based on the ideas that emerged from the multiple theories and conceptual frameworks that were reviewed. Application of this framework guided the structure of the thesis.

The vulnerability of whom to what was conceptualised in the model in relation to hazards and exposure. “To what” in the question dealt with the identification of the hazards while the “of whom” related to the exposed features or livelihoods. This was tackled in two ways in this research: consideration of “temporal exposure” concerned with the frequency, magnitude and duration of the hazard and “spatial exposure” regarding the threatened elements and unsafe conditions. The Standard Precipitation Index (SPI) and interviews of the residents helped to characterise these components. The reasons for the vulnerability of the exposed elements were organised into sensitivity and adaptive capacity. The components (sensitivity, exposure and adaptive capacity) were practically implemented using standard indicators (Adger *et al*., 2006; Cutter *et al*., 2009). The indicators for this framework were derived from existing frameworks such as the sustainable livelihood framework, the double structure framework, the pressure and release model and the environmental change framework (Birkmann, *et al*., 2013; Cuevas, 2010).

The usefulness of the new framework used in this study lies in the fact that it is a combination of several frameworks and therefore utilises the strengths and opportunities of each of these. It is also underpinned by several theories making it robust in analysing and mapping vulnerability. It is open and can take as many indicators as available and was successfully implement in ArcGIS through the weighted sum aggregation technique. At the top of the framework sits the climate system which is modified by the interaction of the human-environment system and which in turn have a direct bearing on the human-environment system as well as the hazards it produces. Thus the framework can be used for the assessment/analysis of vulnerability of any setting or study and could start from the analysis of greenhouse gas emissions. It therefore could provide an opportunity of analysing the interplay between adaptation and mitigation. In characterising exposure in terms of frequency, magnitude and duration, it is able to determine the scale of a hazard at one point in time and therefore also captures the temporal aspect of hazards. It must however, be noted that this framework is by no means better than any framework used for vulnerability analysis but it has the added advantage of integrating theories and frameworks therefore offer robust analysis.

9.2 Challenges and limitations

The major challenge of this research was related to data availability and quality. Most of the data required for the analyses were not readily available. For example, data on soil properties (i.e. texture, bulk density) were needed to estimate the erodibility of the soil and also water holding capacity, and therefore the sensitivity of the soil/agriculture to droughts and floods. Similarly, data on the borehole yields and river flow discharges to study the impact of droughts and dry season on groundwater and floods on river systems respectively could not be obtained from the relevant agencies. Also some of the socio-economic data were at Regional and national levels and disaggregating them to district level meant loss of quality. Another limitation was the translation of the questionnaire and climate related terminologies to the local languages by the research assistants. However, most of the challenges or limitations were overcome through the use of proxies. Proxies have been used for several vulnerability assessments (e.g. Ebert and Kerle, 2008; Damm, 2010; Davies and Midgley, 2010; Barsley *et al*., 2013). The erodibility indicator for instance was mapped using a soil erosion map as a proxy with ratings obtained during the focus group discussions. Most of the adaptive capacity indicators were mapped using proxies. These proxies would have affected the quality of the data as they were of different dates and also were not intended for work like this, so had to be re-calculated. However, their effects were minimised by giving them low weights as have been done in other studies (see Damm, 2010). Additionally, the data used for the mapping, especially the spatial data, were cross-sectional (one-time) data and therefore did not allow for temporal vulnerability mapping to assess repeated impacts on livelihoods and the ecosystem or to assess vulnerability dynamics. That vulnerability is dynamic was highlighted in the literature review. Related to this spatial data problem is also the changing administrative boundaries which affects the use of some socio-economic data for the analysis. Due to the cross-sectional nature of the study, it was not possible to determine the implications of current adaptation options on future vulnerabilities. Despite these limitations, an evaluation of the composite indices developed from these indicators showed that the composites were robust and insensitive to any of the indicators. Thus, the composite vulnerabilities obtained were relied upon to make judgements on relative vulnerabilities of sectors and districts.

In future research of this kind, it will be helpful to obtain a wide range of higher quality data, particularly regarding soil and groundwater, by carrying out in-situ soil analysis and groundwater surveys both in the wet and dry seasons. Future research could be done at community level which is not changing in terms of boundary, and should also make provision for temporal analysis. More local socio-economic surveys could be carried out to determine the adaptive capacity indicators at local level to improve the quality. All these however, will require availability of financial resources. A longitudinal study may allow for analysis of the implications of adaptive actions over the past years to account for future actions. This could help to identify maladaptations and prevent their recommendation within policy.

9.3 Conclusion

Hazards such as droughts, high temperatures, heavy rainfall, floods and windstorms are common in the Upper East Region (UER). The frequency, magnitude and duration of these hazards as well as their impacts vary across space and time and among the climate sensitive sectors. The UER and the Guinea Savannah ecosystem as a whole are highly vulnerable to climate variability and change and the associated hazards. The area is more vulnerable to droughts/high temperatures than it is to floods, and droughts seem to be occurring more frequently than the other hazards. With the projection of increased climatic hazards, all the hazards are likely to increase in their frequency and severity of occurrence. Adaptive capacity in all districts is generally low and unable to balance the current susceptibilities, thus leading to the vulnerabilities. Increasing hazard frequency and severity in the future will mean that plans have to be made to increase adaptive capacities if people want to continue to live in their current locations. Policies must include relevant actions for climate change adaptation such as those discussed in this research. The hazards are real and are having notable effects on the major sectors of the Region's economy. Policies for adaptation need to be implemented now. As the future looks bleak for the Region, policies may have to go beyond adaptation to consider transformation by looking at other options such as resettlement or migration, and investments in other less climate sensitive sectors.

The major contribution of this work is both methodological and empirical in nature, through the multi-hazard approach it has taken to vulnerability mapping. In many studies, vulnerability assessments have often been on single hazards (e.g. droughts or floods) but this study adopted a multi-hazard approach to assess the nature of vulnerabilities as these hazards are sometimes inseparable and occur concurrently or alternately. The analysis revealed that the repeated losses in the agriculture sector, the main economic sector of the Region, is due to the impact of multiple hazards occurring concurrently or alternately. Thus, any adaptation measures should target all the hazards. This will increase productivity in the agriculture sector and hence ensure food security and poverty reduction. The theoretical framework produced from this work is another contribution to the body of knowledge and can be used for any vulnerability assessments. In many vulnerability mapping exercises, weights have been generated from expert judgements, Delphi exercises, or statistics or mathematical formulae. In this work, the weights were obtained from community knowledge and were demonstrated to be robust. Thus, this method of obtaining weights can be used, especially in areas where experts are scarce such as the study area or use of statistics or formulae may not be appropriate.

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Appendix A1 Household questionnaire

Topic: **Hazards and vulnerability mapping for adaptation to climate risks in savannah ecosystem: case study of the Volta basin**

Village Name……………………………………… Questionnaire No. …………

Demographic characteristics

Age of respondent …… Sex ….. Household size …………………

Number of children …… Number of children in school ……………………

Social characteristics

Q3.1 Marital status 1. Married 2. Single 3. Divorced 4. Widowed 5. Other …………

Q3.2 Number of dependents 1. Two 2. Three 3. Four 4. Five 5. Other …

Q3.3 Level of education 1. Primary 2. JHS 3. SHS 4. College 5. University/Poly 6. Other

Q3.4 Number of dependents in school …………………

Q3.5 How many members of your household live outside of your community? 1. One 2. Two 3. Three 4. Four 5. Other …………………

Q3.6 When did they leave the community? 1. Last year 2. Two yrs ago 3. Three to five yrs ago 4. More than five yrs ago

Q3.7 Does their reason for leaving have anything to do with the changing weather patterns? 1. Yes 2. No

Q3.8 If yes, what changes in weather conditions do you think caused them to leave? 1. Increased incidence of floods 2. Increased incidence of drought 3. Increase in temperatures (warmth) 4. Other (specify)……………………………………

Q3.9 Do those who live outside of your community contribute to the upkeep of your household? 1. Yes 2. No

3.10. What kind of contribution do they give you? 1. Money 2. Clothes 3. Building materials 4. Agricultural input 5. Other ……………………………………..

Q3.11 If yes, does the contribution come regularly or only when you are in need?1. Regularly 2. In need

Q3.12 Does it increase when you have a calamity (e.g. crop failure, buildings destroyed)? 1. Yes 2. No

Economic activities

Q4.1. Which of the following economic activities do you engage in? 1. Farming
2. Government work 3. Fishing 4. Trading 5. Artisanal (masonry, carpentry, tailoring, hairdressing, etc) 6. Informal labour 7. Other ………………

Q4.2. Which of the above activities do you use mostly to take care of your family (e.g. food, school fees and books, clothing, etc)? ………………………..

Q4.3. Can you rank these activities that you do to get your income (food & money) in order of importance (starting from the most important)? ………………………………

……………………………………………………………………………………………

Q4.4 Five years ago, were you doing these same activities? 1. Yes 2. No

Q4.5 If no, which activities were you into (list)? ………………………………………

……………………………………………………………………………………………

Q4.6 Also put them in order of importance…………………………………………………

………………………………………………………………………………………

Q4.7 Why did you change if any? ………………………………………………………

………………………………………………………………………………………

Hazards

Q5.1 Which of the following hazards do occur in your area (tick as many as possible)?

1. Floods 2. Droughts 3. Increasing temperature 4. Windstorm 5. High rainfall 6. Other (specify) …………

Q5.3 On a scale of 1 to 10, can you rate the hazards (highest score given to the most disastrous)?

Hazard	score
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….

Q5.3 Do you see any of these hazards occurring in your community as normal and therefore have resolved not to do anything about it (or them)? 1. Yes 2. No

Q5.4 What makes you think so? 1. We believe our norms have been bridged 2. Our actions are causing them 3. They are part of life 4. Other ………………………………

5.5 Which category of people suffer more when there is a hazard? 1. Children 2. Women 3. Aged 4. Youth 5. Men 6. Other …………………………………….

Q5.6 What makes you think so? 1. Shortage of food 2. Spend more time searching for water 3. They become jobless 4. They fall sick due to heat and water scarcity 5. Other

Floods

Q6.1 How often do floods occur in your community? 1. Every year 2. Once in every 2yrs 3. Once in every 5yrs 4. Once in every 10yrs 5. Other (specify) ………….

Q6.2 Did the last worst floods destroy property in your community? 1. Yes 2. No

Q6.3 If yes, which properties were affected by the floods? 1. Houses 2. Farms 3. Roads 4. Schools 5. Health facilities 6. Source of drinking water 7. Other …

Q6.4 Can you tell the quantity of such a property that was destroyed the last time floods occurred in your community (e.g. no. of buildings, acres of farm, etc.)? …………

Q6.5 Over the past 30 yrs, do you think that the quantity/amount of the property affected is increasing? 1. Yes 2. No

Q6.6 Why is the number of properties affected increasing? 1. More waters come now than before 2. More people are settling in flooded areas 3. Because of late farming 4. Other……

Q6.8 Each time the floods occur, what do you by yourself to reduce the effects of the flood? 1. Assist in evacuation of people 2. Seek external aid 3. Do nothing 4. Other……

Q6.9 So what have you done or are you doing now to avoid such an event? 1. Relocated 2. Doing nothing 3. Putting up flood resistant Buildings 4. Planting early in flood prone areas 5. Other …………………..

Q6.10 Does the flood affect your source of drinking water? 1. Yes 2. No

Q6.11 How is your source of drinking water affected? 1. Polluted 2. Cut off because access route is flooded 3. Silted with eroded material 4. Other ………………………

Q6.12 How does this situation affect your life? 1. More time is spent looking for water 2. Increase health burden 3. Spend more money to buy water 4. Water becomes scarce 5. Other …………………………………

Q6.13 How do you cope with this problem? 1. Buy water from Tankers 2. Receive water from NADMO /NGOs 3. Use the polluted water 4. Move to nearby community to fetch water 5. Other …………………..

Q6.14 In your opinion, what do you think is causing the floods to come frequently? 1. More rain falling within a short period of time 2. Increased amount of rainfall 3. Increased runoff 4. Expansion of human activities into flooded areas 5. Other ....

Q6.15 In your opinion, what do you think can be done to reduce/prevent flood impacts? 1. Relocate houses in valleys 2. Stop farming in valleys 3. Plant early maturing crops in flood zones 4. Construct drains 5. Proper disposal of waste 6. Other …………………………..

Q6.16 On a scale of 1 to 10, can you list your livelihood activities and score them on how they are affected by floods (highest score given to the most affected)?

Hazard	score
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….

Drought

Q7.1 Do you observe drought on your farm? 1. Yes 2. No

Q7.2 If yes, how often do you observe this? 1. Every year 2. Once every 2yrs 3. Once every 5yrs 4. Once every 10yrs 5. Other ………………………………..

Q7.3 What effect does the drought have on your farm? 1. Crop failure 2. Hardening of soil 3. Trees dying 4. Other …………………………………………

Q7.4 How do you cope with these situations? 1. Remittances from relatives 2. Rely on government/NGO assistance 3. Community members contribution 4. Other……

Q7.5 Will you say that the occurrence of drought is increasing or decreasing over the past 30 years? 1. Increasing 2. Decreasing 3. Remained the same 4. Other …………

Q7.6 What do you do when there is a drought? 1. Migrate to where it is raining to farm 2. Switch from farming to trading 3. Irrigate our farms 4. Planting drought resistant crops 5. Other …………………………

Q7.7 Apart from the effects on your crops, what other effects does drought have on you or your community? 1. Water scarcity 2. Sicknesses 3. Desertification 4. Death of animals 5. Other …………………………….

Q7.8 What is your source of drinking water? 1. Pipe 2. Borehole 3. Well 4. Pond/Dam 5. Other …………………….

Q7.9 Does your source of water gets depleted when there is drought? 1. Yes 2. No

Q7.10 When this happens, what do you do? 1. We move to the nearby community to get water 2. Use untreated water 3. Buy water from tankers 4. Other ……………

Q7.11 Does the distance to your water source increase when there is a drought?1.Yes 2.No

Q7.12 What effect does drought have on your animals/poultry? 1. Death 2. Wasting 3. Diseases 4. Other ……….

Q7.13 When there is drought how many animals do you lose? 1. Less the 5 2. 5-10 3. 11-20 4. Other ……………….

Q7.14 What are you doing personally or as a community to forestall the effects? 1. Switching to irrigation 2. Planting drought resistant crops 3. Switch from farming to other non-rain dependent activities 4. Other …………………………………

Q7.15 Can you list your livelihood activities and score them from 1 to 10, how they are affected by drought (highest score given to the most affected)?

Activity	score
…………………………………	……………………….
…………………………………	……………………….
…………………………………	……………………….
……………………………….	……………………….
………………………………..	……………………….

Rainfall variability

Q8.1 Over the past 30 years, have you observed changes in the rainfall pattern in your community? 1. Yes 2. No

Q8.2 What changes have you observed? 1. Shortening of length of rainy season 2. Decrease in rainfall 3. Increase in rainfall 4. Increase in dry spells 5. Other ……

Q8.3 What will you attribute the changes to? 1. Cutting down of trees 2. Indiscriminate bush burning 3. Ager of gods 4. Other……………………….

Q8.4 In the past 20yrs, either from your own observation or your parents account, what time was the rainy reason starting? 1. March 2. April 3. May 4. June

Q8.5 What time are the rains starting now? 1. March 2. April 3. May 4. June

Q8.6 In the past, either from your own observation or your parents account, what time were the rains ending? 1. August 2. September 3. October 4. November 5. Other …………

Q8.7 What time are they ending now? 1. August 2. September 3. October 4. November 5. Other ………………………………..

Q8.8 When the rain starts, does it rain regularly throughout the season? 1. Rains regularly 2. There are some breaks 3. Can't tell

Q8.9 If there are breaks, can you tell how long some of the breaks last? 1. Two weeks 2. 3 weeks 3. 1month 4. Other ………………………….

Q8.10 When these breaks occur, what effect does it have on your crops? 1. Crops wilt 2. Stunted growth 3. Other ………………………………….

Q8.11 Does this happen to all the farms? 1. If it stays up to one month or more, all crops will wither 2. If 3 weeks, crops on soils that retain moisture longer survives 3. Less than 3 weeks, crops survive 4. Other ……………………………………

Q8.12 Are the occurrences of these dry spells increasing now than in the past? 1. Yes 2. No 3. Can't tell

Q8.13 How do you respond to the dry spells? 1. Delay in planting 2. Planting short maturing crops 3. Planting drought tolerant crops 4. Other ……………………

Q8.14 Do you see that some traditional crops are disappearing due to the occurrence of dry spells? 1. Yes 2. No

Q8.15 If yes, which ones? ………………………………………………………………

Q8.16 What is the major crop you cultivate? ………………………….

Q8.17 In a normal year of rainfall, how many bags of this crop do you get? 1. 20 2. 30 3. 10 4. 5 5. Other ……………………………….

Q8.18 In a year of bad rainfall, how many bags do you get? 1. 5 2. 10 3. 20 4. 30 5. Other …………

Q7.19 Can you list your livelihood activities and score them from 1 to 10, how they are affected by rainfall variability (highest score given to the most affected)?

Activity	score
……………………………….	……………………….
……………………………….	……………………….
……………………………….	……………………….
……………………………….	……………………….

Temperature

Q9.1 Have you observed any change in temperature? 1. Yes 2. No

Q9.2 What changes in temperature have you observed? 1. Increases in temperature 2. Decreases in temperature 3. Temperature remains the same over the years 4. Other ……

Q9.3 What are the effects of temperature on your livelihoods? 1. Drying of water bodies 2. Desiccation of soils 3. Withering of crops and livestock 4. Increased health burdens 5. Other ………………………………..

Q9.4 Do you fall sick when temperatures are high? 1. Yes 2. No

Q9.5 What type of sicknesses are these? 1. Headache 2. CSM 3. Malaria 4. Cholera 5. Other ………………………………..

Q9.6 Is the number of times you fall sick increasing now than in the past? 1. Yes 2. No

Q9.6 What do you think is accounting for that? 1. Rising temperatures 2. High rainfall 3. Increased Public health awareness 4. Other ……………………………………

Q9.7 What are you doing personally or as a community to forestall the effects? 1. Planting more trees 2. Constructing dugouts to store water 3. Stop bush burning 4. Other………

Q9.8 Can you list your livelihood activities and score them from 1 to 10, how they are affected by temperature (highest score given to the most affected)?

Activity	score
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….

Windstorm

Q10.1 Do you experience windstorms in your community? 1. Yes 2. No

Q10.2 Which time of the year do they occur? 1. Beginning of rainy season 2. Anytime, but only during the rainy season 3. At the middle of the rainy season 4. At the end of the rainy season 5. Other ………………………………………

Q10.3 Will you say the intensity of windstorms is increasing? 1. Yes 2. No

Q10.4 What makes you have the feeling that the intensity of windstorms is increasing? 1. They destroy more properties now than before 2. They uproot more trees 3. More lives are lost 4. Other …………………………………….

Q10.5 Will you say that the number of times you get windstorms now is higher than in the past? 1. Yes 2. No

Q10.6 Can you list your livelihood activities and score them from 1 to 10, how they are affected by windstorms (highest score given to the most affected)?

Activity	score
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….
………………………………	……………………….

Adaptive capacity

Q11.1 Do you practice dry season gardening or farming? 1. Yes 2. No

Q11.2 If yes, where do you get water to water your crops/animals? 1. Dam 2. Pond/dugout 3. Borehole 4. Well 5. Other ……………………………………..

Q11.3 Are you doing this as a measure against drought or dry spell? 1. Yes 2. No

Q11.4 If yes, is this effective in resolving the impacts of droughts? 1. Yes 2. No

Q11.5 How do you get access to land?1. Inheritance 2. Buying 3. Borrowing 4. Other…….

Q11.6 Do you have full ownership of your land? 1. Yes 2. No

Q11.7 Can you use the land for any purpose other than farming? 1. Yes 2. No

Q11.8 How did you acquire the land on which you are farming? 1. Inheritance 2. Buying 3. Borrowing 4. Other……..

Q11.9 If by inheritance, is it from the father's side or the husband side? 1. Father 2. Husband 3. Both 4. Other ………………………….

Q11.10 Do you think the mode of acquisition of land by women is different from that of men? 1. Yes 2. No

Q11.11 Do you have microcredit or financial institution in your community where you can go and borrow money for your business? 1. Yes 2. No

Q11.12 Have you borrowed money from these organisations before? 1. Yes 2. No

Q11.13 If yes, are there limitations or do they require some collateral before granting the loan? 1. Yes 2. No

Q11.14 Do you sense some favouritism in the disbursement of assistance? 1. Yes 2. No

Q11.15 If yes, on what basis?1. Partisan 2. Tribal 3. Sectional 4. Gender 5. Other……

Q11.16 When you get a disaster, does NADMO or any agency respond quickly to help you out of the disaster? 1. Yes 2. No

Q11.17 If no, why did they not respond quickly enough? 1. Information did not get to them early 2. Community is cut off 3. Agencies are far from community 4. Agencies wanted official notification before they respond 5. Other …………………………

Q11.18 How do you cope with disasters? 1. Remittances from relatives 2. Rely on government/NGO 3. Community members contribution 4. Other ……………

Q11.19 Did you receive any information on the disaster before it happened? 1. Yes 2. No

Q11.20 If yes, how useful was the information to you? 1. People moved their properties before the disaster occurred 3. We heard but we could not do anything 4. Information came late 5. Other ………………………………..

Q11.21 How did you get the information? 1. Through mobile phone 2. Radio 3. Television 4. Extension agents 5. Community announcement 6. Other ……………

Q11.22 Where do you buy/sell your produce? 1. In our community 2. In a community about 2km away 3. In the district capital 4. Other ……………………………

Q11.23 How do you convey your produce to/from the market? 1. By head portage 2. By bicycle 3. By motor 4. By motor king 5. By public transport 6. Other …………………

Q11.24 What is the major source of food consumed at home? 1. Own production 2. Buy from market 3. Food aid from government/donor agencies 4. Assistance from relatives 5. Other ………

Q11.25 Do you observe a declining trend in your major source of food? 1. Yes 2. No

Q11.26 If yes, what do you think is accounting for the declining trend? 1. Changes in weather 2. Changes in soil fertility 3. Diminishing land size for farming 4. Rising cost of production 5. Other ………….

Q11.27 What do you do under such circumstances? 1. Reduce food intake 2. Buy food 3. Food from relatives 4. Food from government/external agencies 5. Other ……

Q11.28 Which of the following assets do you have and how do you use them to assist in times of disasters?

Asset	Assistance
Donkey cart	…………………………………………………
Motor king	…………………………………………………
Car	…………………………………………………
Motor bike	…………………………………………………
…………….	…………………………………………………

Q11.29 What do you do as a community to assist those of your members who are hard hit by a hazard? 1. Help in evacuation 2. Offer temporary accommodation 3. Nothing 4. Contribute food items for them 5. Other ……………………….

Q11.30 Is the assistance you offer as a community to your friends who are affected by a hazard enough to help them recover fully from it? 1. Yes 2. No

Q11.31 What type of training or skills did you get? ……………………………………

Q11.32 How does this skill help you to overcome hazards? …………………………….....

Q11.33 What type of roofing material do you use? 1. Mud 2. Thatch 3. Roofing sheets 4. Other………………

Q11.34 What type of building material do you use? 1. Mud 2. Concrete blocks 3. Bricks 4. Other……………………..

Q11.35 What are the problems associated with the type of building materials you use? 1. Rooms collapse after heavy downpour 2. Rooms collapse after flooding 3. Rooms trap heat especially during the dry season 4. Roofs are rift off by storms

Q11.36 How often do you have your rooms destroyed? 1. At least one room per season 2. Not frequent 3. Other………………………

Q11.37 In the face of these problems, what do you do? 1. Reconstruct after destruction 2. Use fans 3. Sit under shade outside during the day 4. Bear with it like that 4. Other…………

Appendix A2 Institutional questionnaire

Department of Geography and Resource Development

University of Ghana

Questionnaire for institutions

The objective of this questionnaire is to find out institutional capacity in adapting to climate. It is not the aim to tarnish the image of any institution/organisation and therefore areas that deal with sensitive issues, do not provide the names of the institutions involved.

Name of institutions/Organization... District ....

1. How often do the following hazards occur in the area?

Hazard	Frequency of occurrence (please use the codes on the right)	Codes	Length or duration of hazard	Codes
Floods		1. every year 2. once in every two yrs 3. once in every 5yrs 4. once in every 10yrs 6. other		1. one month 2. two months 3. three months 4. one year 5. other ....
Drought				
Temperature				
Rainstorm				
Bushfire				

2. Can you score them from 1 to 10 given 10 to the most disastrous/severe?

Hazard	Score	Reasons/criteria for scoring
Floods		
Drought		
Temperature		
Rainstorm		
Bushfire		

3. Can you score from 0 -10, the effects of these hazards on the livelihoods activities

Livelihood activity	Score				
	Drought	Flood	High temp.	High rainfall	windstorms
Crops					
Animals					
Health					
Water					
Houses					

4. What do you think are the causes of these hazards?

Hazard	Cause
Floods	
Drought	
Temperature	
Rainstorm	
Bushfire	

5. What are the effects and at what level of destruction will you say the hazard is severe (i.e. what is the threshold. use the back page if this table is too small)?

Hazard	Effects	Severity
Floods		
Drought		
Temperature		
Rainstorm		
Bushfire		

6. What can be done to minimise the effects?

Hazard	Strategies to minimise effects
Floods	
Drought	
Temperature	
Rainstorm	
Bushfire	

7. Over the past 30 year(s), which year will you describe as the most severe year and what are the indicators?

Hazard	Year of occurrence	Level of Severity				Other variables	
		No. of Lives lost	No. of Livestock lost	No. of farms affected	No. of rooms affected		
Floods							
Drought							
Temperature							
Rainstorm							
Bushfire							

8. What interventions were adopted to respond to the above hazards?

Hazard	Interventions
Floods	
Drought	
Temperature	
Rainstorm	
Bushfire	

9. Based on your own judgment, what percentage do you think the assistance/aid you give meets the individuals' level of destruction or loss?

10. Do you carry out a post assistance/aid assessment to see whether the people are able to put their lives back on track or have adopted your strategies? If so, what is their story (how did they do it)? If no, why not?

11. Does your institution have the capacity to handle following hazards (use 1 for inadequate, 2 for adequate and 3 for well resourced)? Give reasons

Hazard	Level of Capacities							Reasons
		H	F	S	T	I	O	
Floods	yes							
	No							
Drought	yes							
	No							
Temperature	yes							
	No							
Rainstorm	yes							
	No							
	No							

H= human; F=financial; S=skills; T=technology; I=infrastructure; O=other (use back page)

12. What policies, strategies and plans on the impacts of climatic hazards do you have and how do you implement them (please provide answer behind the page if long)?

13. Do you know of any institution(s) working on some of these hazards and how you coordinate with them?

14. What governance structure does your institution/organisation operate (e.g. decentralised system, sole organisation, etc.)? How does this structure help/hinder you in carrying out your duties in relation to adaptation of the society you serve to climatic hazards?

15. What is the level of interference of the following group/institutions on your operations to serve their interest?

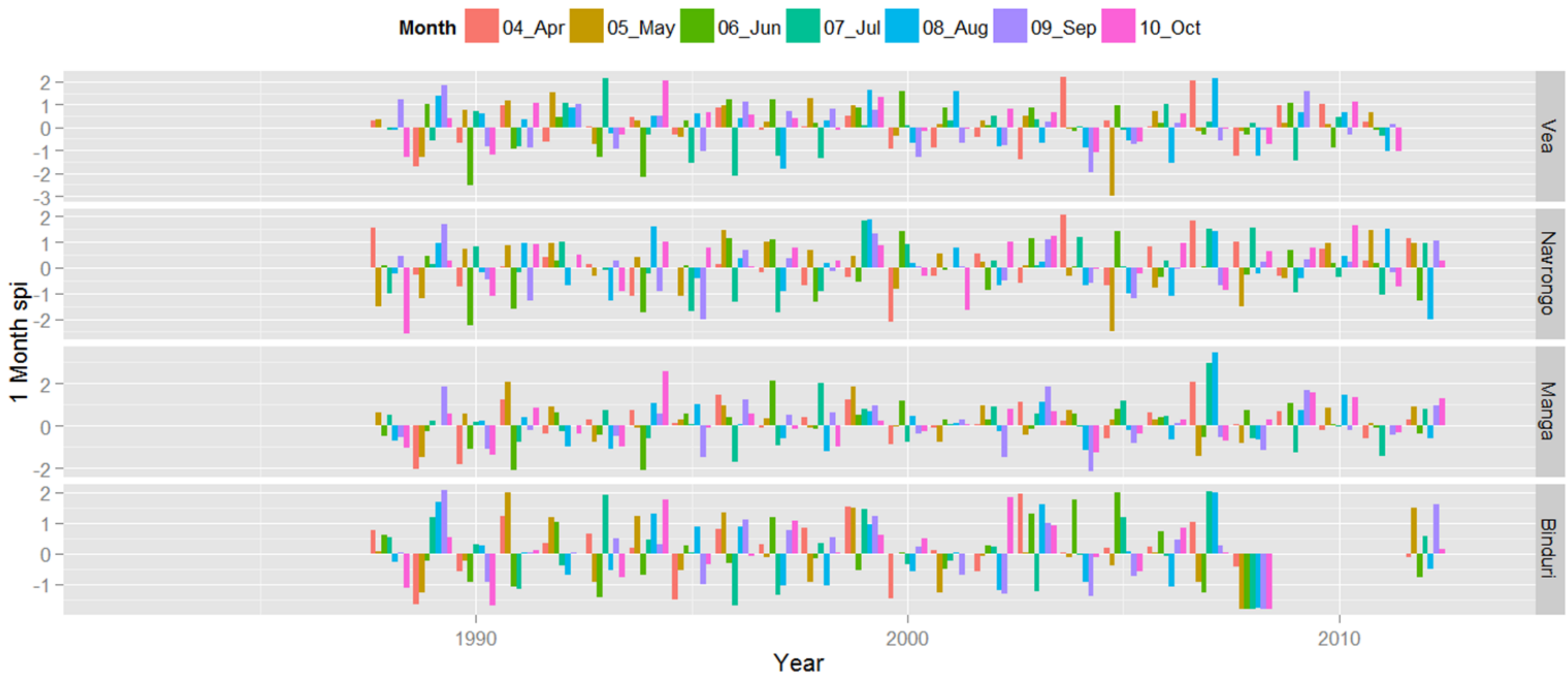
Institution	Level of interference		
	1	2	3
Government of the day			
Member of Parliament			
Assembly Member			
Traditional rulers			
District assembly			
Gender advocates			

1=no interference; 2=low interference; 3=high interference

16. Do you sense that some staff of some organisation request for favours before they act and how does this affect adaptation?

17. Is there anything you think is relevant for this study but is not captured here? Please provide information here and overleaf.

Appendix B Plots of SPI values (April –October, 1988-2012)




Month
04_Apr
05_May
06_Jun
07_Jul
08_Aug
09_Sep
10_Oct
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Year
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Navrongo
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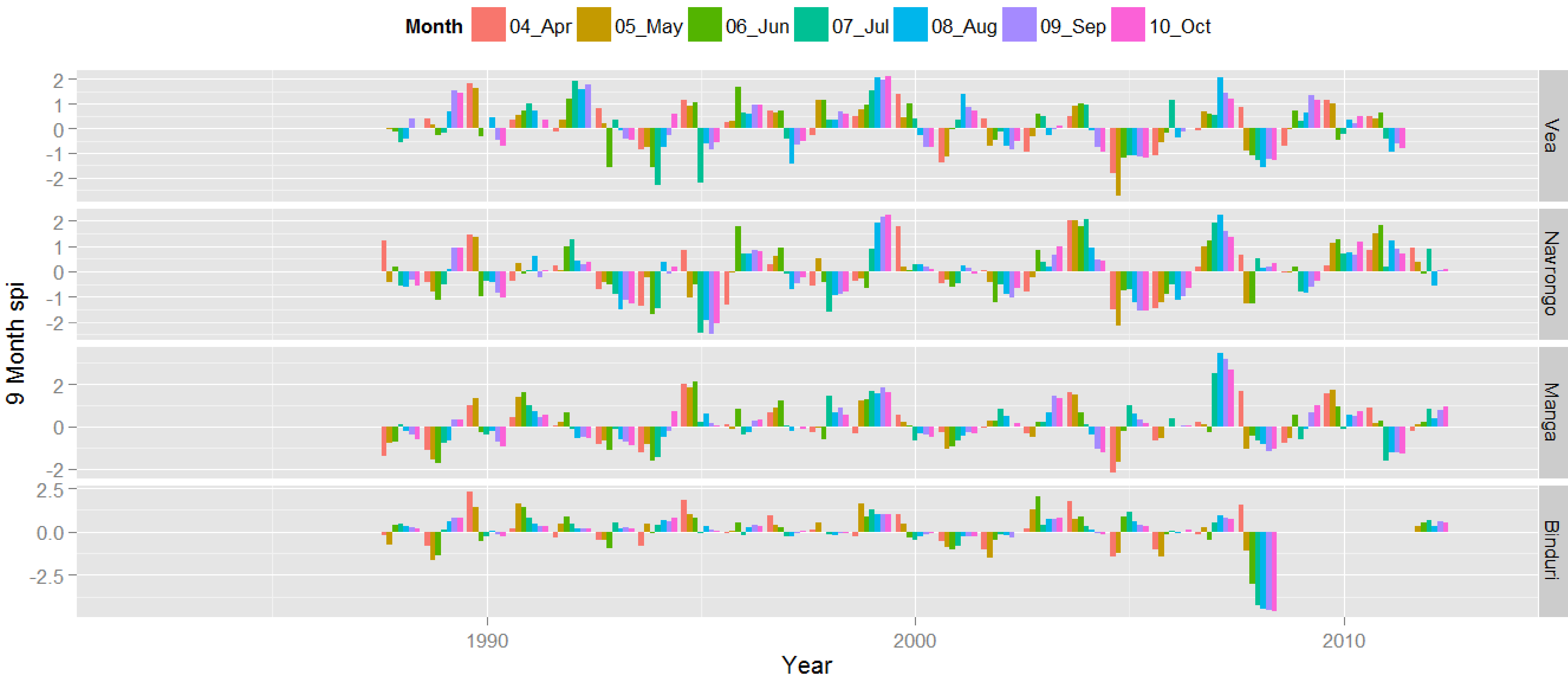
Binduri
1990
2000
2010


Month
04_Apr
05_May
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9 Month spi
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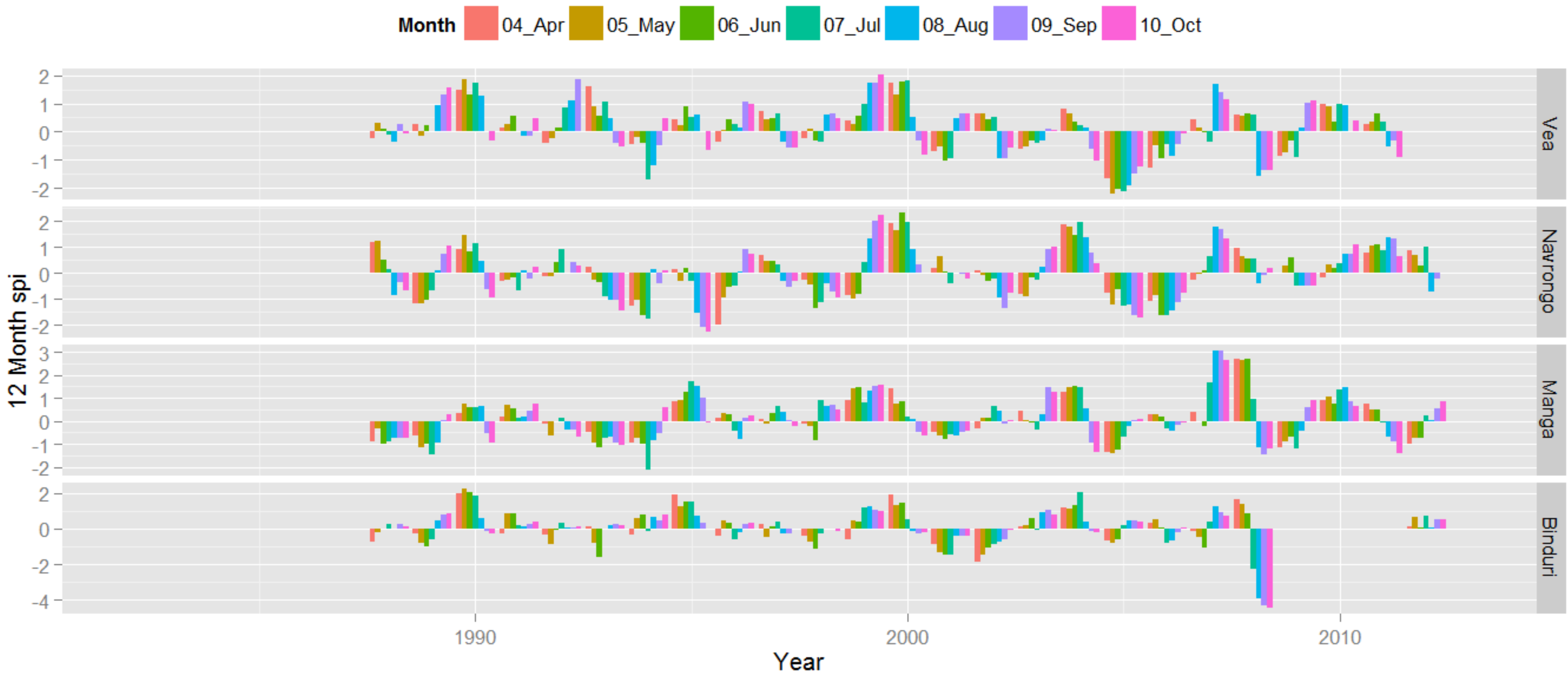
Month
04_Apr
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