UNIVERSITY FOR DEVELOPMENT STUDIES

RICULTURAL LANDS VULNERABILITY TO CLIMATE CHANGE IN HE JIRAPA DISTRICT OF THE UPPER WEST REGION OF GHANA.

PAUL ALHASSAN ZAATO

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AGRICULTURAL LANDS VULNERABILITY TO CLIMATE CHANGE IN THE JIRAPA DISTRICT OF TH UPPER WEST REGION, GHANA

BY

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MPHIL ENVIRONMENT AND RESOURCE MANAGEMENT

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF ENVIRONMENT AND RESOURCE STUDIES, FACULTY OF INTEGRATED DEVELOPMENT STUDIES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN ENVIRONMENT AND RESOURCE MANAGEMENT

MARCH, 2020

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that, this dissertation is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere:

PAUL ALHASSAN ZAATO ……………………. …………………….

o. UDS/MEM/0111/16 Signature Date

ERVISOR'S DECLARATION

eby declare that, the preparation and presenting of the dissertation was supervised in rdance with the guidelines on supervision of dissertation laid down by the University for lopment Studies.

NICHOLAS YEMBILAH ………..………… ………………………..

Signature Date

ABSTRACT

Climate change is a serious environmental threat facing human kind worldwide. It affects agriculture in several ways, one of which is its direct impact on crop production. Ghana, like any country in sub-Saharan Africa, is vulnerable to the effects of climate change. This vulnerability is as a result of the fact that Ghana's economy is dependent on agriculture especially in rural areas where about 90% of the population depend primarily on agricultural related activities for survival. The main objective of the study is to examine the vulnerability of agricultural lands to climate ge in the Jirapa District of the Upper West Region. This study employed the mixed method ;n and 180 sample respondents were randomly selected. Both quantitative and qualitative data collected using household survey, field observation, and interview methods. Accordingly, tudy employed both quantitative and qualitative methods to analyse the data. Rainfall and erature trends were analysed using Simple Linear Regression (SLR) and Standardized pitation Index (SPI). Livelihood vulnerability index was used to analyse the levels of ultural lands vulnerability to climate change supported with percentages, averages, maximum minimum values. The results revealed an increasing temperature, decreasing rainfall and rmal precipitation distribution over the past 57 years. Likewise, the livelihood vulnerability indices (LVIs) calculated for agricultural land and climatic exposure indicators revealed that households are increasingly vulnerable to climate change risks. It is therefore recommended that policy measures and development efforts should focus on improving adaptive capacities of smallholder farmers including enhancing optimum land management mechanisms and provide climate change information, training, education, and required agricultural land inputs to the community.

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DEDICATION

This thesis is dedicated to my mum Madam Magaret Jalu and to the entire Warren Bapong Zaato Family.

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ABBREVIATIONS

Ar	Argon
Co2	Carbon Dioxide
ENSO	El Nino Southern Oscillation
FAO	Food and Agriculture Organization
GHG	Green House Gas
GSS	Ghana Statistical Service
SAT	International Crops Research Institute For the Semi-Arid Tropics
D	International Fund for Agriculture Development
I	International Food Policy Research Institute
C	International Federation of Red Cross and Red Crescent Societies
C	International Panel on Climate Change
Z	Inter-Tropical Convergence Zone
	Livelihood Vulnerability Index
A	Ministry Of Food and Agriculture
MO	National Disaster Management Organization
PDSI	Palmer Drought Severity Index
RDI	Reclamation Drought Index
SWSI	Surface Water Suply Index
UNDP	United Nation Development Programme
USDA	United State Department of Agriculture
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER ONE

BACKGROUND

1.1 Introduction

Climate change is a serious environmental threat facing human kind worldwide. Rural communities in developing countries like Ghana are expected to be affected more due to their ... isive dependence on climate sensitive livelihood options such as agriculture, and limited ... tive capacity to adapt to the changes (UNFCCC, 2009). Climate change affects agriculture in ... al ways, one of which is its direct impact on crop productivity (Ziervogel et al, 2006). Its ... ct would add to the development challenges of ensuring food security and poverty reduction ... ost Sub-Saharan African countries in general (Watson, 2001).

... a, like any country in sub-Saharan Africa, is vulnerable to the effects of climate change. This ... erability is as a result of the fact that Ghana's economy is dependent on agriculture especially ... al areas where about 90% of the population depend primarily on agricultural related activities ... urvival (Adisu *et al*., 2016). Climate change in Ghana is expected to take the form of frequent ... ntense drought, increasing rainfall variability, higher temperatures and may create the loss of productive agricultural lands through the deterioration of ecosystem. These changes are expected to affect crop yields and resource availability (Asante *et al*., 2011).

Northern Ghana accounts for over 40% of agricultural land in the country (Asante *et al*., 2011). Climate data of rainfall and temperature in Northern Ghana shows that the rainfall pattern in Northern Ghana is irregular. This pattern has serious economic impacts on agriculture, particularly in semi-arid regions. Agricultural households in the upper west region largely depend on agricultural lands for farming to sustain their livelihoods. Unfortunately, productive agricultural lands within the region are being exposed to the threats of climate change. Henceforth their livelihoods are threatened.

1.2 Problem Statement

Natural resources of land, water and vegetation are the major providers of goods and services in irapa District. They Natural resources have been experiencing persistent pressures resulting vere land degradation, soil erosion, evaporation and harming of flora and fauna (Sullivan,). In Jirapa district, the distribution of rain within the season is so erratic that it is difficult to ct for any cropping year. Farmers often plant seeds two or three times before rains set in ly. Long spells of drought often punctuate the wet season, leading to partial or total crop es. Weather-related hazards such as drought and flood are frequently occurring, all of which severe effects on farmers' agriculture land resources and overall agricultural productivity. has extremely challenging conditions for farmers with high temperatures, erratic rainfall and d soils resulting in lower crop yields (Amisah *et al*., 2010). The change in climatic conditions deepened the vulnerability of agriculture lands among rural households within the district due to the impacts of climate change. This has led to a reduction in soil fertility, an increase in soil erosion, reduction in soil fauna and flora.

The constant exposure of agriculture lands has led to a decline in output and crop yields which has intern aggravated the food security status and the level of poverty among smallholders whose livelihood is solely dependent on agriculture within the district (IPCC, 2007). Therefore, there is the need to conduct this study to assess the vulnerability levels of rural households to climate change effects with respect to agricultural land within the Jirapa district.

1.3 Research Questions

1.3.1 Main Research question

What is the vulnerability level of agriculture lands to climate change effect?

1.3.2 Specific research questions

(i) How do rural households perceive climate change?

(ii) What is the pattern of rainfall and temperature between 1961 - 2017?

(iii) What are the major climate change related hazards in the study area?

(iv) What is the levels of livelihood vulnerability to climate change?

Research Objectives

Main research objective

ssess the the vulnerability level of agriculture lands to the effect of climate change

Specific Objectives

(i) Examine the perception of rural households on climate change

(ii) Examine the pattern of temperature and rainfall between 1961-2017

(iii) Examine major climate change related hazards in the study area

(iv) Analyse the levels of livelihood vulnerability to climate change

1.5 Scope of The Study

Geographically, the research was conducted in five (5) communities within the Jirapa District of the Upper West Region of Ghana. The District was selected for several reasons: A mode of production based primarily on rain-fed subsistence farming, degraded agriculture lands, a high occurrence of poverty and occurrence of weather extremes such as droughts

Contextually, the study focused on the vulnerability levels of household agricultural lands to ıte change. This is because the menace of climate variability and its associated effects are rienced in the three northern regions especially Upper West and Upper East Regions than any region in the Country.

ignificance of The Study

study analysed rural household vulnerability to climate change with respect to their ultural lands. The findings will help with a better understanding of the vulnerabilities of rural ehold's livelihoods to adverse effects of climate variability with respect to agriculture lands by calculating the livelihood vulnerability indices (LVI) for agricultural land and climate exposure indicators. It is also intended to recommend appropriate strategies to strengthen the resilience of households towards negative effects of climate change as well as the areas of collaboration among the traditional and formal institutions in climate related issues. The study would also provide insights into the perception of households on climate change and the trend of temperature and rainfall patterns within the communities. The study will also reveal the climate related hazards that are presence in the study communities. It is also anticipated that the findings of this study will bridge literature gap, contribute to knowledge and serve as a reference point for further studies in many academic disciplines. Results from the study would provide extension agents with the information necessary to create awareness of the existence of climate change in the study area. Since climate change is location specific, this study would also give insight to the government, extension officers and non-governmental organizations about the provision of adaptation strategies that are appropriate for the communities.

)rganization of The Study

study is organised into five chapters. Chapter one comprises the background, the statement of roblem, objectives, significance and organization of the study. Chapter two reviews existing ture which is in line with the study objectives. In addition, the theoretical and conceptual eworks underpinning the study would be discussed. Chapter three is made up of the study sampling procedures, sample size, research design, research instruments, field work and nistration of data and data analysis. Chapter four presents' results from the data obtained tables and charts and provides a discussion of the analysis of results in relation to the ture reviewed. Finally, chapter five looks at the summary, major findings and conclusion of the study. It also includes recommendations of the study based on the findings which will serve as a guide for policy makers and enhance future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature relevant to the study. The first part of the chapter reviews literature on climate change, the earth's climate system, Africa's climate, climate variability in West Africa, climate baseline and trends in Ghana, temperature and rainfall trends in the upper west region, ıte change related hazards in Ghana, Ghana's agriculture, impacts of climate change on ıa's agriculture land resources, climate change adaptation and mitigation strategies. The ıd part presents the theoretical framework of vulnerability assessment and conceptual ework of the study.

he Rural Area

ous concepts exist concerning what constitutes a rural area. In socio-cultural terms, Hoggart Buller (1987) defined a rural area as a place where traditional and cultural values are iously observed; a place where there is respect for 'elders', the importance of the family, a strong sense of community and suspicion of change in the socio-political status quo. In terms of occupation, a rural area rests on the dominance of primary industry and particularly agriculture and forestry. Hoggart and Buller (1987) further defined a rural area in relation to ecology, as areas in which settlements are small with substantial zones of open country between them.

Ultimately, the definition of rural area is arbitrary and debatable. Whatever the definition for rural area, the point at which rurality ends and urbanity begins is difficult to determine. Based on differences in ecological, economic and sociocultural characteristics, the contemporary definition that is currently used is in terms of population size and this differs for different countries (Boko *et al*., 2007)

For the purpose of this research, the definition given by the Ghana Statistical Servive 2000 Population and Housing Census document of Ghana is adopted. The document describes a rural area in terms of its population size as an area with a population of less than 5000 people. By this definition, about 56% of the Ghanaian population is rural (Ghana Statistical Service, 2010). In Ghana, the rural population rely on agriculture as their main source of livelihood. The rural area e food basket of the country. It is thus important to pay attention to rural agriculture lands to mine their vulnerability levels to climate change.

An Overview of Climate Change

ate refers to average weather conditions of a given geographic region, estimated over a long d of time, usually a few weeks to about 30 years or more (Kopp and Scholze, 2009). Weather e other hand is the state of the atmosphere in a given place at a specific time. Weather has a limited predictability effect and could be directly perceived by people while climate cannot pp and Scholze 2009). Climate varies from place to place, depending on latitude, distance from the sea, vegetation, presence and absence of mountains or other geographic factors (Baede *et al*., 2001).

Akudugu and Alhassan (2012) defined Climate Change as the gradual change in the weather pattern of the world over a long period of time mainly as a result of human activities with respect to the environment. It is among the most important determinants of survival and human livelihoods because it determines how and where human communities live, which foods they can grow, the sources of water for domestic, industrial and other purposes, and how societies and economic activities are organized (IPCC, 2007).

2.3.1 The Earth´s Climate System

The earth's climatic system consists of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere and of the interactions between them rgovernmental Panel of Climate Change 2007).

Earth's atmosphere is composed of nitrogen (N_2, 78.1% volume mixing ratio), oxygen (O_2, % volume mixing ratio, and argon (Ar, 0.93% volume mixing ratio). These gases have limited action with incoming solar radiation and they do not interact with the infrared radiation ed by the Earth. However, there are a number of trace gases, such as carbon dioxide (CO_2), ane (CH_4), nitrous oxide (N_2O) and ozone (O_3), which do absorb and emit infrared radiation. e greenhouse gases play an essential role in the Earths energy budget. Moreover, the sphere contains water vapor (H_2O), which is also a natural greenhouse gas. Because these nhouse gases absorb the infrared radiation emitted by the Earth and emit infrared radiation up- and downward, they tend to raise temperature's near the Earth's surface (IPCC, 2010).

Beside these gases, the atmosphere contains solid and liquid particles (aerosols) and clouds, which interact with incoming and outgoing radiation in a complex and spatially very variable manner. The most variable component of the atmosphere is water in its various phases such as vapor, cloud droplets, and ice crystals. Water vapor is the strongest greenhouse gas (IPCC, 2010).

The hydrosphere is the component comprising all liquid surface and subterranean water, both fresh water, including rivers, lakes and aquifers, and saline water of the oceans and seas. Fresh water runoff from the land returning to the oceans in rivers influences the oceans composition and circulation. The oceans cover approximately 70% of the Earth's surface. They store and transport a large amount of energy and dissolve and store great quantities of carbon dioxide.

The cryosphere, including the ice sheets of Greenland and Antarctica, continental glaciers and snow fields, sea ice and permafrost, derives its importance to the climate system from its high reflectivity (albedo) for solar radiation, its low thermal conductivity, its large thermal inertia and, especially, its critical role in driving deep ocean water circulation (IPCC, 2010).

tation and soils at the land surface control how energy received from the Sun is returned to tmosphere. Some is returned as long-wave (infrared) radiation, heating the atmosphere as the surface warms. Some serve to evaporate water, either in the soil or in the leaves of plants, ing water back into the atmosphere. Because the evaporation of soil moisture requires energy, noisture has a strong influence on surface temperatures. The texture of the land surface (its hness) influences the atmosphere dynamically as winds blow over the land's surface (IPCC,).

marine and terrestrial biospheres have a major impact on the atmospheres composition. The influences the uptake and release of greenhouse gases. Through the photosynthetic process, both marine and terrestrial plants store significant amounts of carbon. Thus, the biosphere plays a central role in the carbon cycle, as well as in the budgets of many other gases, such as methane and nitrous oxide. Many physical, chemical and biological interaction processes occur among the various components of the climate system on a wide range of space and time scales, making the system extremely complex (Wang *et al.*, 2013).

The climate system is driven by energy received from the sun. Some of this energy is reflected back into space, but the rest is absorbed by the land and ocean and re-emitted as radiant heat. Some of this radiant heat is absorbed and re-emitted by the lower atmosphere in a process known as the greenhouse effect. The earth's average temperature is determined by the overall balance between the amount of incoming energy from the sun and the amount of radiant heat that makes it through the atmosphere and emitted to space. A crucial feature of the climate system is that the sun's energy is not distributed uniformly, but rather is most intense at the equator and weakest at the poles. This non-uniform energy distribution leads to temperature differences, which the atmosphere and ocean act to reduce by transporting heat from the warm tropics to the cold Polar Regions. This non-ırm heating and the resulting heat transport give rise to ocean currents, atmospheric lation, evaporation and precipitation which we experienced as weather (Wang *et al.*, 2013).

ıfrican's Climate System

ːa's climate is very diverse and highly variable. It encompasses the extreme aridity of the ran deserts at one end of the range and the extreme humidity of the Congo rainforest at the ·. Interacting with these natural patterns are the combined effects of anthropogenic global ıing and human interference more generally (Collier, 2008).

The African climate is in itself determined at the macro-level by three major processes or drivers: tropical convection, the alternation of the monsoons, and the el niño-southern oscillation of the Pacific Ocean. The first two are local processes that determine the regional and seasonal patterns of temperature and rainfall. The last is more remote in its origin, but strongly influences the year to year rainfall and temperature patterns in Africa. Adding to tropical deforestation, pasture land degradation and biomass burning of the savannahs contribute to the anthropogenic greenhouse gases effects (Conway, 2002).

The Inter-Tropical Convergence Zone (ITCZ) releases enormous heat. It is the major source of the planet's atmospheric warming. Africa is also a source of the Atlantic hurricanes that often develop from easterly atmospheric waves passing over Africa at the time of the monsoon (Conway, 2002).

Wind-borne dust also produces large quantities of aerosols. The effects of aerosols on climate are highly complex. In certain circumstances, some aerosols reflect incoming radiation, thereby ng the planet, but others trap the heat and add to the greenhouse effect. Dust can either reduce imulate rainfall. In low clouds, water attaches to dust particles and prevents droplets from ming heavy enough to fall. But in high clouds dust particles over wetter regions may provide ces for ice crystals to form around them, resulting in greater rainfall (Nicholson, 2013).

Climate Variability In West Africa

climate of West Africa is characterized by high inter-annual variability and significant inter-dal variability. There is a clear warning signal as all locations in West Africa were warmer, verage, in the 2000s than in the 1970s. The 2000s were particularly warm in the northern part e region with parts of Mali and Mauritania been at least 1.5°C warmer in the 2000s compared to the 1970s. However, it is also apparent that in some locations more recent decades have been cooler than preceding decades; for example, Togo, Benin, western Nigeria and southern Mali were all warmer in the 1980s than in the 1990s (IPCC, 2007).

The 1980s was a particularly dry decade for much of the region, which coincides with Sahel drought that caused considerable hardship to communities across the region. By contrast, the 2000s were slightly wetter for much of the region, with the exception of Guinea, Sierra Leone, southern Mali and southern Ghana.

Lebel and Ali (2009) suggest that, while there has been a recovery of the rains in eastern parts of West Africa, there has been a continuation of drought conditions in western regions, which is consistent with the observed data. In a recent review, Druyan (2011) notes that, the 1990's seasonal rainfall accumulations over the Sahel have somewhat recovered, but not to the levels seen in the 1950s.

Changes to temperature and precipitation extremes in West Africa observed since the 1950s, with the period 1961-1990 used as a baseline, include increase in temperature of warmest and coolest increasing frequency of warm nights, decrease in cold nights, increased dry spell duration greater inter-annual variation in dry spells in recent years. Because of sparse and unreliable rvations across much of West Africa, and given statistical issues associated with deriving s in extremes for short sampling periods, all of the findings are stated with medium dence. It was also stated that there has been a decrease in the amount of rainfall received in y rainfall events, while stating that rainfall intensity has increased, which seem somewhat adictory. An earlier study by New *et al*. (2006) showed evidence of increase in dry spell ions and rainfall intensity, with the observed trends for temperature extremes more apparent for precipitation.

2.4.2 Climate Baseline and Trends In Ghana

Ghana has three hydro-climatic zones; the Volta basin system, the South-Western basin system, and the Coastal basin system. The South-Western system is the most humid part of the country, with mean annual rainfall between 1500 mm and 2000 mm. The Volta basin system, covering the northern part of the country, has mean annual rainfall of about 1000 mm in the savanna area and about 1500 mm to 2000 mm in the forest area. The Coastal basin system is the driest, with mean annual rainfall of about 900 mm. The rainfall is controlled by the movement of the tropical rain belt which oscillates between the northern and southern tropics over the course of a year. The major climatic processes are shown in Table 2.1 below.

Table 2. 1: Major Climatic Processes

Major Climate Processes	**Impacts on climate**
El Nino Southern Oscillation (ENSO)	Brings warmer and drier than average conditions in the south in December-March, wetter than average conditions in the north, particularly in November-May
r-Tropical Convergence Zone (ITCZ) and st African monsoon	Brings rains as it oscillates north-south. Creates a shift between the two opposing prevailing wind directions

ce: Druyan (2011)

Ghana’s climate is tropical and strongly influenced by the West African monsoon. Two main rainfall regimes are identified (Asante *et al*., 2011):

(i) the double maxima regime occurring south of latitude 8º30`N, with two maximum periods occurring from May to August and from September to October; and

(ii) The single maximum regime found north of latitude 8^{0}30`N, where there is only one rainy season from May to October, followed by a long dry season from November to May.

In northern Ghana, the wet season occurs between May and November, when the ITCZ is in its northern position and the prevailing wind is south-westerly, and the dry season occurs between December and March, when the 'Harmattan' wind blows north-easterly. The south-eastern coastal strip is dry and different from the north and the south (Asante *et al.*, 2011).

The major rainfall and temperatures patterns form the basis of the agro-climatic zones namely, the Sudan Savanna zone, the Guinea Savanna zone, the Transition Zone, the semi-Deciduous forest zone, and the High Rainforest Zone. Each zone is represented geo-climatically by ongo, Tamale, Wenchi, Kumasi, and Axim, respectively (Asant *et al*., 2011).

ɩuzono *et al* (2013) summarized climate baseline trends for Ghana as follows:

i) Mean annual temperature has increased by 1.0˚C, at an average rate of 0.21˚C per decade. The rate of increase has been higher in the northern regions of the country than in the south.

ii) The average number of 'hot' days per year increased by 48 between 1960 and 2003.

iii)The average number of 'hot' nights per year increased by 73 in the same period.

iv) The average number of 'cold days per year decreased by 12 (3.3% of days) between 1960 and 2003.

(v) The average number of 'cold' nights per year decreased by 18.5 (5.1% of days) in the same period.

(vi) Annual rainfall in Ghana is highly variable on inter-annual and inter-decadal timescales and long-term trends are difficult to identify.

(vii) Rainfall over Ghana was particularly high in the 1960s, and decreased to particularly low levels in the late1970s and early 1980s, producing an overall decreasing trend in the period 1960 to 2006, with an average precipitation of 2.3 mm per month (2.4%) per decade.

(viii) There is no evidence of a trend in the proportion of rainfall that has occurred since 1960.

2.4.3 Climate Change Future Projections in Ghana

rally, climate models cannot project changes in regionally driven climate phenomena, such NSO. Thus, for Ghana climate models show a wide range of projected changes in the itude of future El Niño type of events. As the climate in Ghana is strongly influenced by O, this contributes to uncertainty in climate projections. Projections of precipitation changes ie Sahelian and Guinea coast regions of Africa are strongly divergent and most models fail to oduce realistic inter-annual and inter-decadal rainfall variability in the Sahel in 20th century lations. This adds to the uncertainty in the projected changes (IPCC, 2010).

ral studies have been undertaken to reveal overall climate trends for Ghana in the future. e include the World Bank study of the Economics of Adaptation to Climate Change Study he 2000 UNDP Climate Profile of Ghana from the period of 2060-2090. Among their findings are the following:

(I) Mean annual temperature is projected to increase by 1.0 to 3.0°C by the 2060's, and 1.5 to 5.2°C by the 2090's. The projected rate of warming is most rapid in the northern inland regions of Ghana.

(II) Temperatures in the northern regions are projected to increase by 2.1–2.4°C, in the western, western-central, and Volta regions by 1.7–2.0°C, and in the Brong Ahafo region by 1.3–1.6°C.

(III) Projections indicate substantial increases in the frequency of days and nights that are considered ‘hot’ in current climate, but the range of projections between different models is large. Total annual rainfall is projected to decline by 1.1%, and 20.5% in 2020 and 2080, respectively.

(IV) Seasonality is projected to change, with early termination of rainfall in the transitional zone, and is likely to convert the current bi-modal regime to a uni-modal one.

(V) The projections for precipitation indicate a cyclical pattern over the period 2010–2050 for all regions, with high rainfall levels followed by a drought every decade or so. The wettest parts of the country are expected to be the Tropical and Moist Deciduous Rainforest zone (in the Ashanti and Western regions) and Coastal zone (Volta, Eastern, Central, and Greater Accra regions). The northern and southern Savannah zones are projected to be relatively dry.

VI) The proportion of total annual rainfall that falls in ‘heavy’ events tends toward increases and there is a trend in the projections toward a decrease in January-June rainfall (dry season), and increases in July-August rainfall (wet season), suggesting that the wet seasons are projected to get wetter and the dry seasons drier.

(VII) Projected changes in 1- and 5-day rainfall maxima tend toward increases, but projections vary a great deal.

(VIII) Sea level rise is projected at 5.8 cm, 16.5 cm and 34.5 cm by 2020, 2050, and 2080, respectively.

Overall, Ghana is projected to become hotter and wetter during the wet season and drier during the dry season, with increased sea level rise and storm surges.

2.4.4 Temperature and Rainfall Trend in The Upper West Region

The climatic regime of Upper West Region is semi-arid with annual rainfall of 700-1200 mm with a mean for three stations over 25 years of 989 mm. The rain falls in a seven-month season from April to October (IFAD, 2006). But according to the Ghana Meteorological Department of late the rains start in June rise to its peak and decline sharply almost a dry spell in October. According to IFAD, farmers agree that the overall quantity of rain falling is declining and the distribution is unfavorable than before (IFAD, 2009).

mean monthly temperature of the region ranges between 21^{o}C and 32^{o}C. Temperatures ases to its peak (40^{o}c) in March, just before the onset of the rainy season and decline to their num (20^{o}c) in December during the harmattan. However available data show an approximate ase of 1^{O}C over nearly five decades in the region (IFAD, 2009).

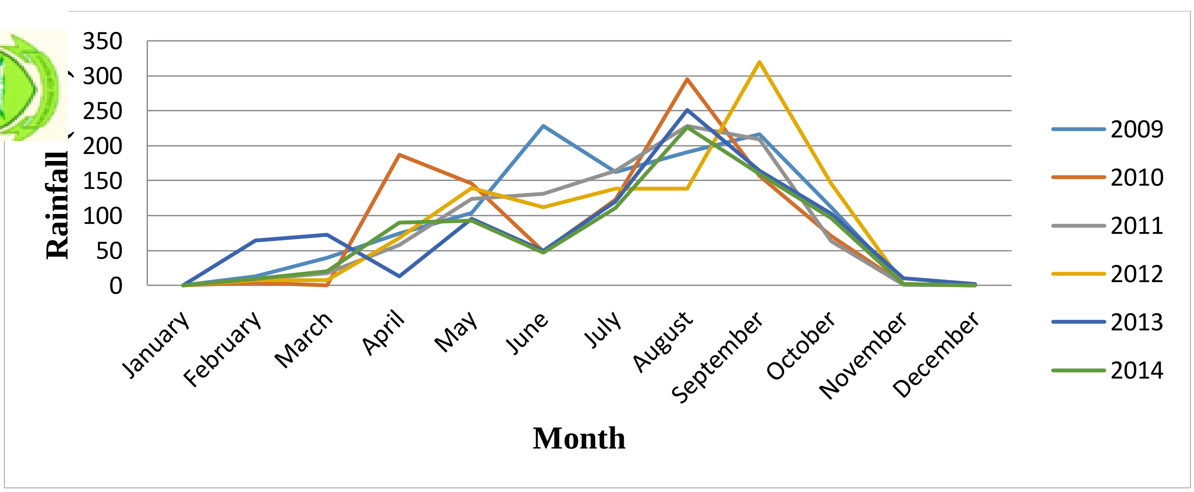
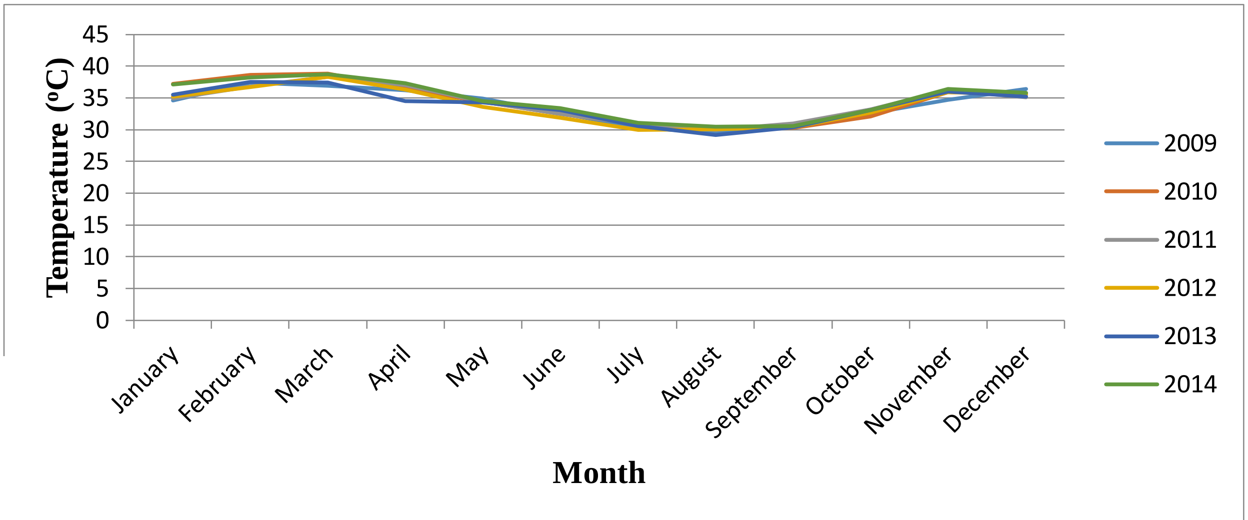


Figure 2. 1: Monthly rainfall distribution of the Upper West Region from 2009-2014

Source: Upper West Regional Meteorological Department, 2015



re 2. 2: Monthly temperature distribution of the Upper West Region from 2009-2014

ce: Upper West Regional Meteorological Department, 2015

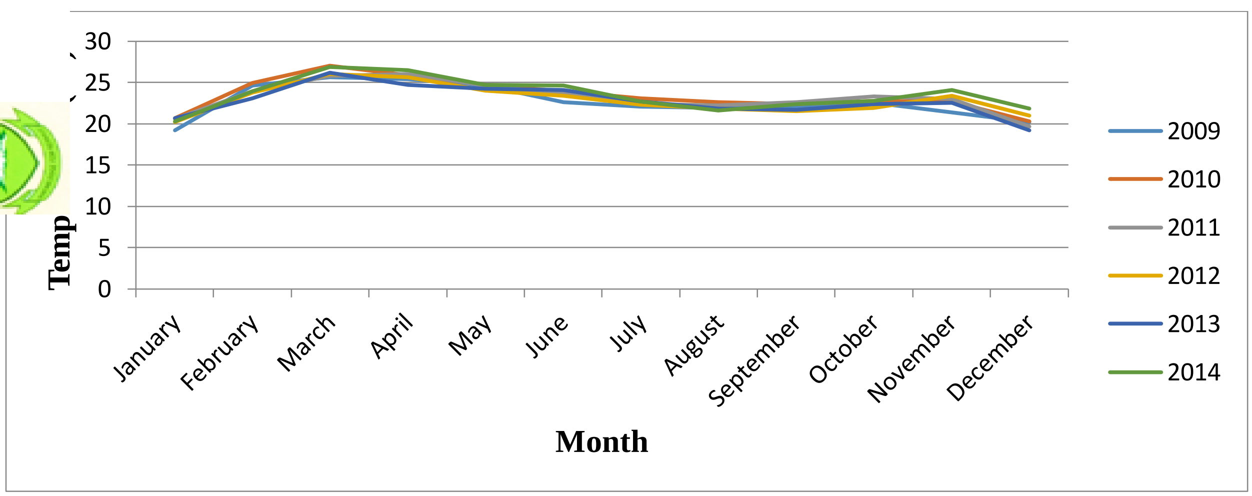


Figure 2. 3: Monthly mean minimum temperature for the Upper West Region from 2009-2014

Source: Upper West Regional Meteorological Department, 2015

2.5 Climate Change Related Hazards in Ghana

Climate hazards is defined as an event with the potential to cause harm, such as heavy rainfall, drought, storm, or long-term change in climate variables such as temperature and precipitation" Climate hazards may occur suddenly or slowly (e.g. droughts); they may be transient (e.g. storm) or permanent (e.g. increase in average temperatures); and may be observed in the present or cted to occur in the future (UNDP, 2007)

ent development dynamics and demographic changes in Ghana put more people at risk from ters as a result of increasing rural poverty, rapid urbanization, growth of informal settlements, urban governance, and declining ecosystem and land conditions. With more than 60% of a's population depending directly on agriculture, the impacts of localized disasters are likely ve even greater accumulated impacts on rural livelihoods over time because of climate change DP, 2007).

e impacts are likely to be more obvious in the north, where soil erosion is pronounced and rty among crop farmers is high. Overall, the impacts of climate risks are likely to magnify the uneven social and spatial distribution of risk in Ghana, and possibly amplify poverty in the North.

2.5.1 Floods and Droughts in Ghana

Ghana is exposed to floods, particularly in the northern Savannah belt and faces associated risks of landslides. Climate extremes amplify food security threats and can severely affect economic development. Insufficient rainfall during the major cropping season during the last major severe drought in 1982-1983, affected more than 12 million people. Also, the 2007 catastrophic floods in northern Ghana occurred immediately after a period of drought and damaged the initial maize harvest. Extreme rainfall events have increased over the 1986-1995 period, including a high number of 24-hour maximum rainfall events—a trend that has continued in the last decade.

Droughts have received much more attention in the literature than floods. Wet years are usually referred to as good years (Van der Geest, 2004). Excess rainfall is, however, harmful to crops like millet and sorghum during particular phases of plant growth when excessive rainfall causes very severe floods in which people lose their lives and property. And this has become a critical issue ıakert *et al.*, 2010).

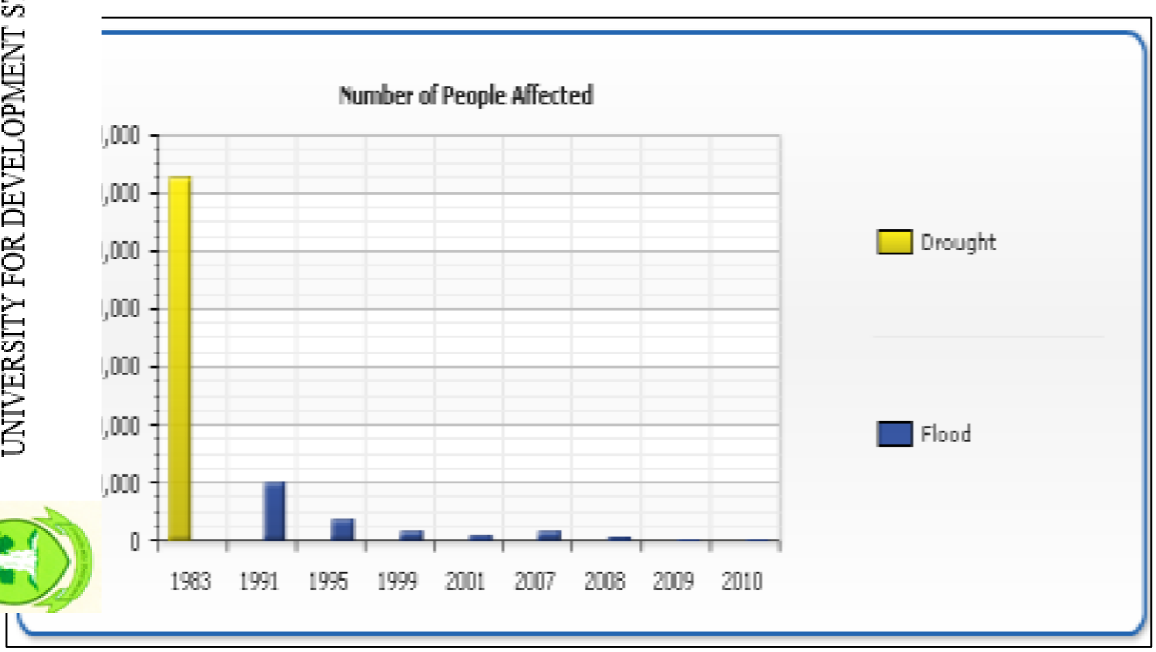


Figure 2. 4: Number of people affected by floods and droughts 1983-2010

Source: Van der Geest, 2004

Recent examples of dramatic flood events in Ghana are the 2011 floods in Accra and floods in the three Northern Regions which killed 56 people and affected 330,000 people (Danquah, 2013). More recent is the June 3rd, 2015 flood disaster that claimed over 200 lives, displaced 9,255 and affected 46, 370 people (IFRC, 2015). The less extreme circumstances, where excess rainfall at inappropriate periods results in severe declines in yields for particular crops or even sometimes complete crop failure are usually ignored. This is undoubtedly because of prevalent disasters like the Sahelian famines of the late 1970's and early 1980's was triggered by shortages of rainfall rather than excess rainfall. When there is abundant rain, although some crops may fail, other crops like rice and sweat potatoes does very well (Van der Geest, 2004). Mishra and Singh (2010) differentiate four (4) types of drought. The physically measurable droughts are meteorological ght, agricultural drought, and hydrological drought. Groundwater drought and socioeconomic ghts constitute the non- physically measurable droughts.

.1 Meteorological Drought

eteorological drought is a temporary shortage of rainfall significantly below the regular or cted amount in a month, season or year. The analysis of meteorological droughts is paratively easy because they are chiefly defined in statistical terms (Mishra and Singh, 2010). eteorological drought in a certain area can be defined as a situation in which the rainfall is ient by at least two times the standard deviation of the average (Mishra and Singh, 2010).

In identifying meteorological drought, Palmer (1965) proposed an index known as the Palmer Drought Severity Index (PDSI). PDSI is a widely used index to measure drought. According to Peng *et al.*, (2012) PDSI is measured as follows: based on the principles of a balance between moisture supply and demand, in the calculation man-made changes are not considered. The index generally ranges from -6 to +6, with negative values denoting dry spells and positive values indicating wet spells. PDSI scores are standardized to local climate and are able to demonstrate the regional condition of drought. It includes average temperature, total precipitation, parametrization of soil type and water holding capacity of the top layers of the soil. The effects of this type of drought are determined by characterizing how rainfall deficiencies vary depending on geographic location.

Monthly PDSI values were averaged at a Climate Division level between 2000-2016 as a component indicator for Exposure in this study. Another index commonly used is the Standardized Precipitation Index (SPI), which was developed by McKee, *et al*. (1993) to quantify a precipitation deficit for different time scales.

.2 Agricultural Droughts

:ultural droughts happen when crops have inadequate water to grow adequately and produce :actory yields. Since diverse crops and grasses have distinct moisture needs at different stages ant growth, the arrival of an agricultural drought in a particular area is difficult to describe, :ularly when a large variety of crops is being cultivated (Van der Geest, 2002).

ght can also be defined by associating drought to the crops or fodder cultivated in an area der Geest, 2002). Descriptions and explanations of agricultural drought can be expressed in ght indices like the Palmer Drought Severity Index (PDSI), Rainfall Anomaly Index (RAI), Moisture Index (XMI), Bhalme and Mooly Drought Index (BMDI), Surface Water Supply Index (SWSI), National Rainfall Index (NRI), Standardized Precipitation Index (SPI), and Reclamation Drought Index (Mishra and Singh, 2010). Monitoring agricultural drought is difficult, since soil moisture needs of crops depend on the type of crop, the seed variety, the sowing date, the stage of plant growth and physical and chemical characteristics of the soil on which the crop is cultivated (Mishra and Singh, 2010).

2.5.1.3 Hydrological Drought

Hydrological drought, is defined as a deficiency in water supply that is associated with decreased river flow, reduced reservoir and lake storage, and lowered groundwater levels (Yevjevich, 1967). The effects are based on the negative impact of water resource availability caused by below normal stream flow or decreased volume of lake or groundwater. Hydrological drought occurs when a community receives below normal precipitation for a number of years and they no longer have ;s to water supplies to sustain their livelihood as their reservoirs and nearby rivers are depleted. e agricultural droughts normally happen soon after meteorological drought, there is a time val in the advent of a hydrological drought (Mishra and Singh, 2010). When the agricultural ght ends, the hydrological drought can still remain a long time because it takes a longer time reams, lakes, rivers, dams and groundwater to be replenished than for soil water (Mishra and ı, 2010).

es used to monitor this type of drought are the Surface Water Supply Index (SWSI) or the ımation Drought Index (RDI) for determining water supply and runoff deficiencies. These es, take the demand for water into consideration, restricting water use and water rationing sually the solutions to deal with this type of drought.

2.5.1.4 Socio-Economic and Groundwater Drought

Socio-economic drought arises when a lack of precipitation results in inadequate supply of goods in comparison with the demand for that particular good. In contrast with the first three categories of drought, socio-economic droughts are not measurable in physical terms. Socio-economic droughts depend on the market conditions of that particular area (Mishra and Singh, 2010).

Groundwater droughts generally occur on a time scale of months to years. For groundwater drought, the total amount of water available is difficult to define. Even if it can be defined, in most groundwater systems, negative impacts of storage depletion can be felt long before the total storage is depleted. Therefore, most often a groundwater drought is defined by the decrease of groundwater level. However, groundwater storage, or groundwater recharge or discharge can be and has also been used to define or quantify a groundwater drought (Mishra and Singh, 2010). Van der Geest (2002) also identified an ecological drought, which happens "when the primary productivity of a ·al or managed eco-system falls significantly owing to reduced precipitation." For all these ;ories of drought, the impact is particularly severe when many following years are dry (Van ;eest, 2002).

ıgle stress can have various impacts, of diverse nature and time scale, droughts reduces the ability of water and grass as the watering points and moisture content are reduced, grasses :rops cannot grow well. Some pastures are no longer accessible and animals cannot grow to naturity and produce satisfactorily (Gitz and Meybeck, 2012). Prolonged or repeated drought has long lasting degrading effects on land. A combination of drought and over cultivation and grazing, particularly near watering points, destroys the vegetative cover, increases soil erosion anu degrades the land (Gitz and Meybeck, 2012). These combined effects of droughts reduce productivity (crops and livestock), and increases household vulnerability. Moreover, they reduce the value of assets (crops and livestock) and productive capital for the future and consequently food and livelihood insecurity. Assessing potential impacts of a stress on a system requires not only evaluating the potential impact of each of the components of the system, but also how it will change the relationships between the components of the system. It is particularly difficult for complex systems involving biophysical factors, as these cannot be totally reduced to a single dimension (Gitz and Meybeck, 2012)

2.6 Ghana's Agriculture

Ghana's agriculture consists of a range of agricultural products. The agricultural sector offers employment on a formal and informal basis to the population of the country (Mensah, 2003). Crop uction forms the major percentage of the agricultural subsector. It constitutes about 66.2% of ntire agricultural output in the country (G.S.S, 2010).

crop production subsector produces a range of crops in different climatic zones which span the arid savanna to the wet tropical forest. Agricultural crops, including yams, groundnut, va, grains, cocoa, oil palms, kola nuts, and timber, form the base of agriculture in the economy hana (Clark and Nancy, 1994). About 155,000 km^2 (68%) of total land area of Ghana is idered as agricultural land (World Databank, 2013). Approximately 78,500 km2 of the total area is under cultivation also 300 km^2 is under irrigation. Smallholder rain-fed peasant ing using rudimentary tools, methods and technologies forms the majority of the agricultural r accounting for 80% of overall agricultural production. Agriculture is largely on a smallholder scale in the Country.

Approximately 90% of farm holdings are below two hectares in size. However, there exist some farms that are large and are used, principally for rubber, oil palm and coconut cultivation. The traditional system of farming is the main farming system in the country. The hoe and cutlass are the dominant farming tools frequently used by farmers. Mechanized farming is less pronounced. Agricultural production differs with the amount and distribution of rainfall received in an area. Soil fertility is an important factor affecting crop production. Most food crop farmers practice mixed or intercropping. Mono cropping is usually associated with larger-scale commercial farms (MOFA 2011).

The major crops cultivated in Ghana include cereals, fruit, legumes, roots and tubers, vegetables and industrial crops (FAO 2001). Staple crops include cereals, roots and tubers, and legumes. Fruits and vegetables supply vital micronutrients, and industrial crops are essential cash crops for export returns. Both physical and biological characteristics of the agro-ecosystem, and social and economic indicators, suggest what crops and farming systems will generate the greatest output or risk for the farmer and the household (Stutley, 2010).

e are large regional differences across Ghana in agricultural structure and activities (Stephen,). The forest zone is from an economic point of view the most important agricultural ucer, accounting for 43 % of agricultural GDP. This is to a large extent due to the large area coa that contributes not only to agricultural income, but also Ghana's exports. The area of a in Ghana constitutes about 1.6 million hectares, which is equivalent to the total cereal area. coastal savannah zone contributes 10% of agricultural GDP and the remaining 47% is buted across the other savannah zones.

staple crops that include cassava, yams, taro, sweet potato and plantain constitute about 1,9 mill. ha, which is about equal to the area of cereals and pulses combined. The growth in agricultural production in Ghana has been mainly driven by land expansion and the growth in productivity remains a challenge. The cultivated land expanded by 60% over the period from 1994 to 2006, but has been slowing lately (Stephen, 1996). Cocoa has been the main driver of land expansion. The low yields in agriculture are mainly caused by low soil fertility and insufficient use of modern technologies such as fertilizers and improved seeds.

2.6.1 Impacts of climate change on Ghana's Agriculture

Agriculture which is the largest employer in the Ghanaian economy suffers the most from climate change. The distribution of rainfall is the most important factor affecting agriculture. The increasing variability of rainfall increases the risk associated with farming because predictions have become almost impossible. Total rainfall amounts are projected to fall or experience great variability which will impact crop production and the livelihoods of many in rural areas. The social ıts of climate variability include changes in land tenure arrangements and social relations, ation and subsequent urban vulnerability.

cultural production is predominantly rain-fed and any changes in rainfall pattern would have us impact on productivity. Current projections on climate indicate that rising temperatures frequent droughts will increase the incidences of bushfires and environmental degradation. changes in the climatic conditions in the past have deepened rural vulnerability to poverty and nced the process of land degradation and desertification. Investments in agriculture are ming expensive, risky and less profitable. These changes in climatic conditions have caused ive and negative effects on agriculture. However, in developing countries studies have ated more negative effects that cut across crop, livestock and fisheries production. Maddison, (2006) posited that variation in temperature caused adverse decline in crop production through increase in pest infestation.

According to FAO (2008), fluctuations in precipitation and prolonged drought negatively affect crop productivity. Besides these impacts of climate change on crop productivity, there is evidence of impacts on livestock productivity and fishery production. The Ghanaian economy is agriculture driven with about 60 per cent of the population involved in the growing of crops and rearing of livestock at the subsistence level as a means of survival (ADB, 2011). This implies that majority of land in the country is mainly used for agriculture (MOFA, 2008). By implication, Ghana's agriculture is rainfed; the production of crops and animals is entirely at the mercy of the weather. The agricultural sector is paramount in poverty reduction in most developing countries as majority of rural household's livelihood depend on this sector. In Ghana the sector is dominated by smallholder farmers who cultivate about 1–2 hectares of land and produce 80% of the country's agricultural output. In spite of the importance of the agricultural sector, it is the most vulnerable sector in developing countries when issues of climate change are discussed since the sector mostly nds on rainfall.

.1 Impacts of Climate Change On Crop Production

ate change can affect crop production in a variety of ways. Beyond a certain range of eratures, warming tends to reduce yields because crops speed through their development, ucing less grain in the process (IPCC, 2007). And higher temperatures also interfere with the y of plants to get and use moisture. Evaporation from the soil accelerates when temperatures nd plants increase transpiration. Excessive rainfall as a result of climate change leads to floods h destroys arable lands, impairs crop growth, increases growth of weeds and post-harvest s. A significant reduction in rainfall may culminate in drier land; reduce water level in streams and rivers; increases farmers' search for water for irrigation and consequently result in reduction in crop yield (Ozor, 2009).

Highlighting on the impacts of climate change on crop productivity, Stutley (2010) confirms extreme temperature in Ghana to be the source of low yields in the crop production. Similarly, Mendelsohn et al. (2006) contends that, extreme temperatures and prolonged drought in Ghana were the major cause of low crop productivity. According to Tonah (2010), planting periods for crops in Ghana have changed over the years from early April in the 1960's to late April or early

May 1960's. These changes were attributed to unpredictable nature of rains and changing environmental conditions especially in the amount and distribution of rains. These changing rainfall patterns affected cereal production and the production of roots and tubers (Daze, 2009). However, climate change does not only reduce crop production thereby causing food insecurity at local or national levels but also increases the incidence of pests and diseases in crops posing serious threats to human health and the attainment of livelihoods (Ampaabeng and Tan, 2012).

For Ghana, using 2000 as the base year, yields of maize were projected to decrease by about 15% 050 (Jones and Thornton, 2003). Schlenker and Lobell (2010) showed that compared to ıge yields over the period 1961-2006, mean yields of maize, sorghum, millet and groundnuts lecrease by about 20% towards the middle of the century (2046-2065). Using crop yields for as the base year, Nutsukpo et *al.* (2012) found that by 2050, climate change would cause an ıll yield decrease of less than 25% for rain fed maize and rice and above 25% for groundnuts. ever, regional variations in yield were observed to yield increases as was projected in some (De Pinto *et al*., 2012).

.2 Impacts of Climate Change on Livestock

Kabubo-Maria (2008), reports the effect of climate change on the quality of feed available for livestock production. Climate change could affect livestock and dairy production. The pattern of animal husbandry may be affected by alterations in climate, cropping patterns, and disease vectors. Higher temperatures as a result of climate change could likely result in a decline in dairy production, reduced animal weight gain and reproduction and lower feed-conversion efficiency in warm regions (Keane, 2009).

Climate change could also expose livestock to disease infections due to changes in temperature. Incidence of diseases of livestock are likely to be affected by climate change, since most diseases are transmitted by vectors such as ticks and flies, the development stages of which are often heavily dependent on temperature (Eagle *et al*., 2010). Cattle, goats, horses and sheep are also vulnerable to an extensive range of nematode worm infections, most of which have their development stages influenced by climatic conditions. This can impede the production of livestock and slow down the rate of development in this sector.

ate change could limit the availability of water for irrigation and fish production. When water es recede due to evaporation arising from an increase in temperature, there would be a decline ter availability for irrigation purposes, and reduce fish production (Dube, 2013). When large r bodies recede, whole economies suffer. Examples: Egypt and Kenya rely on the Nile for tion; Guinea, Mali, Niger and Nigeria depend on the river Niger, for food, water and port, and Ghana on Volta River for same (Nair, 2009). The implication of the above is a ne in the production of livestock, resulting in a reduction in the supply and availability of al protein including meat, egg, milk and other animal produce such as hides and skins (Ozor,).

2.7 Farmers' Livelihood Amidst Changing Climate

Climate change has threatened the livelihood of millions in developing countries, especially the very poor through direct impacts on livelihood sources (Chambwera and Stage, 2010). Diverse cultural systems, socio-economic conditions and environmental exposures makes household 's sources of income vulnerable over time (Egyir *et al*., 2013). Some livelihood assets such as agricultural production knowledge and tools become redundant, influencing sustainable livelihood strategies- ways of combining and using assets are jeopardized as climate becomes increasingly variable (Egyir *et al*., 2013).

Amidst such eventualities, opportunities for livelihood diversification become critical in determining community and household ability to cope with climate related stresses and shocks (Duncan, 2004). Climate variability and change through diverse stimuli and intervening factors affect economic, social, cultural and natural conditions of individuals and communities, altering the value and usefulness of various livelihood assets (Duncan, 2004). livelihoods connote the ıs, activities, entitlements and assets by which people make a living (Elasha et al., 2005). e are spread across social, natural, financial, human and physical assets as outlined by the ırtment for International Development (2001).

loping adaptive capacity to minimize the damage to livelihoods from climate change is to nd a necessary strategy to complement climate change mitigation efforts. An understanding e nature of local livelihoods – what types of livelihood strategies are employed by local people vhat factors constrain them from achieving their objectives are very important. According to DB (2011), such an understanding cannot be gained without social analysis so that particular l groups and their relationship with factors within the vulnerability context can be identified.

2.7.1 African Farmers Livelihood Security

Climate change has been found to impact agricultural output, vary ecological boundaries and the location of flora and fauna species. This adversely affects the livelihood of communities' dependent on primary occupations such as agriculture that is directly dependent on nature (Glazebrook, 2011). For agriculture dependent households, changes in rainfall and temperature makes their livelihoods vulnerable (UNDP, 2007). Climate shocks such as droughts, floods and thunderstorms tend to destroy crops and cause increased food prices (UNDP, 2007). The opportunity to engage in alternative livelihood activity is therefore critical in ensuring that households are cushioned to against these shocks and stresses arising from climate change.

In parts of Eastern and Southern Africa, climate change has negatively affected agriculture, water sources and quality, biodiversity, health and ecosystems which are key components of local livelihood assets (Colls and Ikkala, 2009). The rate of change has marginalized already vulnerable livelihoods, made those that could have adapted more slowly less adaptive and handicapped new hood opportunities in the near future (UNDP, 2007). Some livelihood alternatives that ers resort to include seasonal migration of livestock keepers and distribution of livestock herds fferent places; rainwater harvesting; and doing casual labour to be able to get food and other ehold needs, selling of livestock, engaging in small businesses, including shops, local urants and kiosks (Kangalawe and Lyimo, 2013).

erability of an individual depends on his/her assets base, the choice pattern and use of these s. With limited livelihood assets, the response of vulnerable individuals and communities l be unsustainable or even maladaptive. Inefficient institutional policies and processes could act to amplify shocks and stresses at the local level (Kangalawe and Lyimo, 2013). This restricts livelihood strategies and corresponding livelihood outcomes. The ability to adapt to future trends of climate change and variability can be determined by using current coping and adaptive capacity as a proxy (Elasha et al., 2005). Hence the less appropriate their coping and adaptive capacity, the more vulnerable their livelihoods will be to future stresses

2.7.2 Security of Farmers' Livelihoods in Ghana

Reduction in rainfall, variation in rainfall patterns, droughts, and high temperatures are some evidence of climate change in Ghana. These have affected the livelihoods assets of communities exposing them to hunger and poverty (Akudu and Alhassan, 2012). Floods and bushfires caused by high temperatures have destroyed farmlands, biodiversity and wild-life which are the basic natural capital that rural people depend on for their livelihoods (Akudugu and Alhassan, 2012). Diversification, encompassing migration, non-farm work and social support networks, in addition to livestock production, according to Roncoli *et al*. (2009) has moderated the adverse effects of climate variability on farming households.

Hunting and gathering of wild fruits, charcoal production and chain saw operations are important ng strategies and a means of building assets that have become common in Ghana (Yaro, 2013). (2013) includes petty trading, security work, craftsmanship, salaried work and production elling of charcoal and firewood emphasizing that in Ghana, people 's livelihood depends on ing and other off-farm income generation activities. However, McCarthy (2001) submits that ng is the predominant alternative livelihood activity among smallholder farmers.

farmers also migrate to more vibrant and economically productive areas to sell their labour. eke and Zeller (2012) explain that when the rains are poor, farmers commit more labour rces to less risky alternative livelihood activities. Hence, sale of labour to off-farm livelihood ities lessens the impact of their vulnerability to rainfall on household income and food supply. However, Yaro (2013), pointed out that storing wealth in the form of healthy livestock has been challenged by the suspension of free government programs in eliminating livestock diseases. This was a source of investment aiding adaptation of livelihoods in times of shocks and stress, hence

building resilience. The resilience of livelihoods must be prioritized in climate change and adaptation deliberations (Tonah, 2010).

The collection and sale of shea nuts, dawadawa, fuel wood and wild fruits has become major livelihood options, especially during the lean season in Africa (Yaro, 2013). In 2007, the three Northern Regions of Ghana experienced flooding that destroyed houses, displaced families, and destroyed farmlands eroding natural, social, and physical assets. Households lost their livelihoods and the resources to engage in alternative livelihood activities were scarce (Akudugu and Alhassan, 2012). Amidst such dire situations, the collection of shea nuts and dawadawa provided a source of income in the short term as these are readily available across the Northern regions of ıa.

e most farmers have sought alternative livelihood options, there have been some exceptions is trend. According to Elasha *et al*. (2005) involvement in alternative income generating ities besides agriculture has not been prioritized in some parts of Ethiopia. This although not ly outlined could be due to some form of security that complement such needs. The United s Department of Agriculture (2015) purports that the relevance of alternative livelihoods rs from farm to farm, reducing as farm output increases. Off-farm livelihood engagements are cent times significantly contributing to the income sources of agriculture based households ted States Department of Agriculture, 2015). These alternative livelihood activities provide a window of hope to which agriculture based households whose income and food supply is threatened by CVCC can channel limited capital and labour resources to yield outcomes that ensure continuous household food and income supply (Biazin *et al*., 2012).

In Ghana, off-farm income appears to be an important component of incomes, particularly for relatively labour-abundant households within scarce land environments (McCarthy and Sun, 2009). Effective development policies must improve livelihoods by enhancing people's capabilities, improving equity, and increasing the sustainability of resource use. A livelihoods perspective in the climate change discourse must place people at the center of the analysis, located within, rather than dominated by, ecosystems, technologies, governments, markets, experts, or resources (Tonah et al., 2013). These must be geared towards expanding farmers' asset base to enable them engage in varied livelihood strategies that yield sustainable livelihood outcomes.

2.8 Climate Change Adaptation and Mitigation Strategies

Climate change adaptation refers to deliberate adjustments in natural or human systems and vior's that involve set of actions, strategies, processes, and policies that respond to actual or cted climatic stimuli (effects) in order to reduce the risks on people's lives and livelihoods C, 2007). Climate change mitigation refers to actions or interventions to reduce the potentially ful effects of global warming by reducing Green House Gases (GHG) emissions or the spheric concentration of GHG and also sequester or store carbon in the short term, and lopment choices that will lead to low emissions in the long term (IPCC, 2007).

e 2. 2: Adaptation Option for Ghana's Agricultural Sector

Options	Short-term Options	Mid to Long-term Options
Dealing with risk and uncertainty	(i) Weather and climate information services and early warning (ii) Crop insurance (iii) Raising of awareness and access to information (iv) Participatory planning or collective action (v) Flood control	(i) Climate modelling, impact and vulnerability assessment (ii) Strengthening seed systems

Farming practices and technologies	(i) Indigenous knowledge (ii)Drought/flood resistant varieties (iii) Crop diversification and specialization (iv) Improved crop practices and production technology (v) Pest and disease control (vi) Adaptive water management and moisture control (vii) Soil conservation and erosion control (viii) Fertilization (x) Changing of plot locations (xi) Irrigation Extension services and training	(i) Indigenous knowledge (ii)Drought/flood resistant varieties (iii) Crop diversification and specialization (iv) Improved crop practices and production technology (v) Pest and disease control (vi) Adaptive water management and moisture control (vii) Soil conservation and erosion control (viii) Fertilization (x) Changing of plot locations (xi) Irrigation Extension services and training
Off-farm practices and strategies	(i) Improve post-harvest, food storage practices (ii) Empower communities and females (iii) Improve access to credit	(i) Improve access to land or tenure rights (ii) Migration (iii) Disease prevention
National development policy	(i) Agricultural intensification and land use policy (ii) Access to and governance of water (iii) Transportation and other infrastructure (iv) Market and price reform (v) Institutional reform (vi) Financial incentive for specific practices or inputs	(i) Agricultural intensification and land use policy (ii) Access to and governance of water (iii) Transportation and other infrastructure (iv) Market and price reform (v) Institutional reform

	(vii) Education (viii) Reduce inequality or poverty, especially in the North	(vi) Financial incentive for specific practices or inputs (vii) Education (viii) Reduce inequality or poverty, especially in the North

De Pinto et al., 2012

Soil and water conservation in agriculture

in larger efforts at agricultural intensification, is an important response for ensuring food ·ity that has clear links with adaptation to climate change. Key practices include timely access ·m inputs, contour-ridge tillage, stone lines, tied ridges, terracing, crop residue management mulching, zaï pits, agroforestry, farmer-managed natural regeneration of field trees, and vater harvesting (Barron *et al*., 2010). Conservation agriculture principally links to adaptation ıgh its effects on reducing soil erosion and storm water runoff and increasing soil water ng capacity, which enhances water productivity (Barron et *al.*, 2010).

ɜxtent to which the above conservation practices have become normalized in dryland ecosystems of West Africa is unclear. An important example of positive large-scale change in semi-arid agricultural landscapes is in southern Niger. In this country, farmer managed natural regeneration of field trees across more than a million hectares has shifted the trajectory of agricultural landscapes towards restoration and resilience (WRI, 2008). Improved land tenure security, decentralization of tree ownership from the state to local communities, the presence of markets for fodder tree products, together with the abatement of severe drought conditions in the Sahel contributed to this transformative change. A common counter narrative to this success story is where lack of land tenure security creates a strong disincentive for investment in land improvements as in the case of Mali (Ebi *et al.*, 2011) and undermines the ability to use land resources to manage shocks, as in the case of Burkina Faso and northern Ghana

2.8.2 Soil and nutrient management

According to FAO the availability of nitrogen and other nutrients is essential to increase yields. This can be done through composting manure and crop residues, more accurate matching of ents with plant requirements, controlled release and deep placement technologies or using nes such as macuna for natural nitrogen fixation. Using methods and practices that increase ic nutrient inputs, retention and use are therefore essential and minimizes the need of etic fertilizers which, due to cost and access, are often unavailable to smallholder's peasant ers and through their production and transport, contribute to GHG emissions (FAO, 2010).

conservation techniques are increasingly practiced in Ghana and several African countries. A conducted by Lema and Majule (2009) in Manyoni District of Tanzania revealed that farmers menyanga and Kintinku ensure good timing of different farming activities, burying of crop ues to replenish fertility of the soil, burning crop residues to promote quick release of nutrients and allowing livestock to graze on farmlands after the harvesting of crops so as to enhance soil organic matter (Lema and Majule, 2009).

2.8.3 Water Management—Small Reservoirs and Irrigation

Small reservoirs are another important risk management strategy widely deployed in West Africa. Small reservoirs offer multiple-use potential to better meet household and livestock water needs, and to expand irrigation to diversify towards high-value market production and thus reduce reliance on climate-sensitive rain fed production. Such structure could offer a viable mechanism for expanding irrigation in the region appropriate with adaptation goals, though there are potential ıside risks related to upstream-downstream water resource access.

ɐ has been a significant investment in small reservoirs throughout Burkina Faso and Ghana the last few decades (Glazebrook, 2011). With over 1,050 small and medium-scale reservoirs, ina Faso has one of highest density of reservoirs in the region (Leemhuis et al., 2009), and in ıern Ghana there are nearly 950 small reservoirs and dugouts (Namara et al., 2010).

Water Harvesting and Use

oved water harvesting and retention (such as pools, dams, pits, retaining ridges, etc.) and r-use efficiency (irrigation systems) are primary for increasing crop productivity and addressing the increasing irregularity of precipitation patterns. Currently, irrigation is practiced on 20 percent of the agricultural land in developing countries. However, it generates 130 percent more yields than rain-fed systems. The expansion of efficient management technologies and methods, especially those relevant to smallholders is essential (FAO, 2010).

Degraded farmlands have been reclaimed by farmers in the Yatenga province, by digging planting pits, known as zaï. Increasing the depth and diameter of the pits and adding organic matter improves this traditional technique of farming and makes it more efficient. The Zaï concentrate both nutrients and water and facilitate water infiltration and retention (FAO2010). This traditional technique has improved yields of crops on lands which used to be barely productive thereby increasing farmer productivity and efficiency.

2.8.5 Change in Cropping Pattern and Calendar of Planting

Climate change negatively influences crop production through long-term variations in precipitation causing changes in cropping pattern and calendar of operations (Akinnagbe and be, 2014). In Tanzania, to avoid crop production risks as a result of rainfall variability and ght, staggered planting is commonly practiced by most farmers whereby crops are planted e the onset of rains (dry land) on uncultivated land. Some farmers plant crops immediately rain, while others plant a few days after the first rains. These were purposely done to spread by making sure that any rain was utilized to the maximum by the crops planted in dry field nnagbe and Irohibe, 2014).

Access to Seasonal Weather and Climate Information

Seasonal climate forecasts and long-range weather forecasts are viewed as an important tool for bolstering climate risk management capabilities, particularly in rainfed agriculture and particularly during periods of a strong El Niño or El Niña that tend to coincided with unusually wet or dry years (Roncoli *et al.*, 2008). Mostly, though seasonal forecasts have not realized their potential in Africa because they are presented in a way that is not actionable. The forecast-development process lacks sufficient input from, and coordination with, end users; and end users lack understanding of, or trust in, the forecasts and thus do not act on the information (Roncoli *et al*., 2008).

Mali is often noted as one of the exceptional countries in West Africa with respect to its use of seasonal climate information in the agricultural sector. For example, the Mali Meteorological Service has had a long-running program in which they give rain gauges to farmers so that farmers can use insitu rainfall measurements in conjunction with weather advisories from the meteorological services to make decisions about planting dates and varieties to plant (USAID,). In turn, the rain gauge data collected by farmers is conveyed back to the meteorological ces and to a multi-agency, which feeds this information to agricultural services agencies n the government.

eover, elite capture of technologies, a common problem in Africa, is evident in this case as groups tend to be heavily skewed towards male farmers with wealth and assets, and women ers are largely excluded as there are no advisories tailored to crops that women cultivate. No it reviews of the Ghana Meteorological Service were available during the period that this was piled. However, one innovative approach in northern Ghana appears to be helping to advance f climate information.

The Climate Change Adaptation and Food Security CCAFS and ESOKO program provides weather forecasts together with recommendations about when to prepare lands and plant, and when to harvest, via mobile phones in all local languages. With a short code of 1900 a farmer can call for information and the call center of ESOKO can response in local languages at very inexpensive call rates. ESOKO sends text messages to farmers regarding weather forecast and other climate related information as well as prices of commodities and where to buy seeds. Farmers are also allowed to report any agriculture related information to ESOKO.As reported at the focus group discussions with farmers in northern Ghana, it is now common to hear 'what is ESOKO saying today' among farmers.

2.8.7 Farming System and Livelihoods Diversification

Diversification of farming system and livelihoods is another example of a risk management strategy with clear implications for adapting to climate change. In Burkina Faso, for example, communities are diversifying away from high reliance on climate sensitive crop and livestock uction (Nielsen and Reenberg, 2010), though the extent to which climate is driving this sification versus that of other socio-ecological and economic factors is not clear.

ırkina Faso, recent agricultural intensification and diversification efforts seem to be motivated by increasing land scarcity and new market opportunities than by climate risks. Similarly, orthern Ghana, increasing demand from urban markets, not climate risks, is spurring sification towards irrigated vegetable production (Nielsen and Reenberg, 2010), and towards ıg and other non-farm income sources (Assan et al., 2009). Charcoal production also provides ıportant source of livelihoods diversification in northern Ghana though one with important onmental downsides (Assan *et al*., 2009).

2.8.8 Afforestation and Agroforestry

Tree planting is the process of transplanting tree seedlings, generally for forestry, land reclamation, or landscaping purposes. It varies from the transplantation of larger trees in arboriculture, and from the lower cost but slower and less reliable distribution of tree seeds (Akinnagbe and Irohibe, 2014). It entails growing seedlings over an area of land where the forest has been harvested or damaged by fire or disease or insects. Rural farmers in several African countries have been planting trees as a way of adapting to the effect of climate variability and change. Agroforestry is a rational land-use planning system that seeks to find some balance in the growing of food crops and forests (Akinnagbe and Irohibe, 2014). In addition to the fact that agroforestry techniques can be perfected to cope with the new conditions that are expected under a drier condition and a higher population density, they result in an increase in the amount of organic matter in the soil thereby improving agricultural productivity and decreasing pressure exerted on forests (Akinnagbe and Irohibe, 2014).

Improved Irrigation Efficiency

ess of climate variability and change adaptation is heavily dependent on availability of fresh r in drought-prone areas. As water becomes a limiting factor, improved irrigation efficiency become an important adaptation tool, especially in the dry season, because irrigation practices ry areas are water intensive. Climate change is expected to result in the decline of fresh water ability (surface and groundwater) and minimize soil moisture during the dry season, while the water demand is expected to rise due to high evapo-transpiration resulting from climate ge and the continuous introduction of high-yielding varieties and intensive agriculture. As erature increases, farmers tend to irrigate more frequently. Irrigation has become an adaptation strategy to warming. Also when precipitation increases, farmers tend to irrigate less often and resort to the use of rainfall (Akinnagbe and Irohibe, 2014).

2.9 Theoretical Framework of Vulnerability Assessment

2.9.1 Conceptual Framework

This section deals with an interactive compilation of the indicators, concepts and the major components of climate change leading to vulnerability and its consequences. Vulnerability as a function of sensitivity, adaptive capacity and exposure with some indicators relevant to establishing the vulnerability of agricultural lands to climate change.

sure, defined as the degree of climate stress upon a particular unit of analysis may be sented as long term changes in climate variability, including the magnitude and frequency vents (IPCC, 2001). The unit of analysis for which exposure was determined is the land. The farmland 's liability to flooding was determined.

tivity is the degree to which a system will be affected by climate stimuli (Smith et al.,). Adaptive capacity is the ability of a system to adjust, modify or change its icteristics and actions to moderate potential future damage, take advantage of rtunities and cope with the consequences of shock or stress (Brooks, 2003).

erability assessment is the process of identifying, quantifying, and prioritizing (or ranking) the vulnerabilities in a system. Examples of systems for which vulnerability assessments are performed include information technology systems, energy supply systems, water supply systems, transportation systems and communication systems. Vulnerability variable assessments measures the vulnerability of selected variables of concern to specific sets of stressors. Vulnerability is defined as changes that have occurred or will occur in these selected variables (e.g., income) or stressors. This method can assess relationships across a wide range of stressors to the extent that, the selected stressors characterizing a given place, provide important indications of its vulnerability (Luers *et al*., 2003).

Vulnerability has its origins in natural hazard and food security issues (Cutter, 1996). Vulnerability is considered to be the ability to anticipate, resist, cope with and respond to hazards (Wisner *et al*., 2004). Vulnerability to climate change is considered to be high in developing countries due to social, economic and environmental conditions that amplify ...ptibility to negative impacts and contribute to low capacity to cope with and adapt to ...te hazards. There is need for the developing world to understand the threats of climate ...ge to agriculture, formulate policies that will lessen the risks and take action (Leary ...Kulkarni 2007). The determinants of vulnerability do not operate in isolation, and ...ly interact in complex ways (Boko *et.al*., 2007).

...ate-sensitive resources such as local water supplies and agricultural land; climate ...tive activities such as arable farming and livestock husbandry; and natural resources ... as fuel-wood and wild herbs will be conspicuously impacted by climate change and ...bility. These impacts can reduce the availability of local natural resources, limiting ...ptions for rural households that depend on natural resources for consumption or trade (Boko *et al*., 2007).

Climate change has affected the farmers' land resources and that exacerbate their exposure and sensitivity to climatic risks. Exposure to high frequencies and intensities of climate risk deteriorate agricultural land and in turn reduce crop yield. The IPCC's definition of vulnerability contains the integrated vulnerability assessment approach to measure the vulnerability levels of farmers with respect to agricultural land (IPCC 2007).

Land refers to cultivated land (Ellis, 2000), soil fertility and topographic features that can affect the ability of the people to generate means of survival and adapt to climate change (Maddison, 2006). Vulnerability is represented by farm size, farmland location, crops produced, and changes in climatic conditions such as unexpected flood, increasing temperature, decreasing rainfall and increasing frequency of extreme weather events. Thus, areas with unexpected flood, increasing temperature and decreasing rainfall and increasing frequency of extreme weather events will be identified as areas more exposed to climate ge (Ellis, 2000).

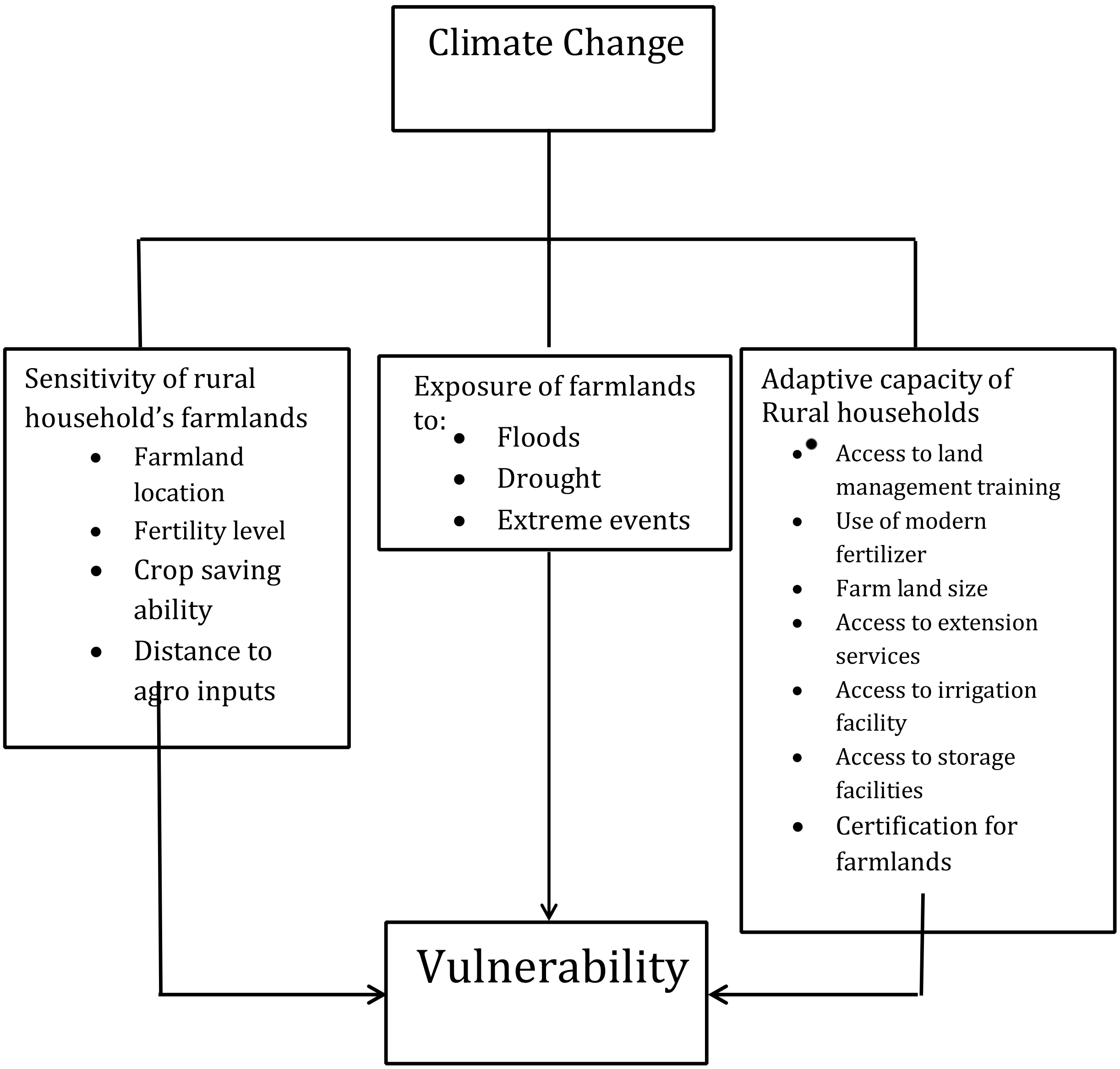


Figure 2. 5: Conceptual framework to vulnerability assessment

Source: adapted from Deressa, 2010

2.9.2 An Index Approach to Study Vulnerability to Climate Change

According to Coltman *et al*. (2008), In many literatures quantitative assessment of vulnerability is done by developing vulnerability index. It is based on several set of variables producing a single number that can be used to compare various regions and sectors. Leichenko *et al*. (2004) argues that a good measure of the validity of the index is the internal correlation between the individual indicators used in the index. The relevance of this criterion will, depend on the relationship between the indicators and the construct they are intended to measure (Coltman *et al*., 2008).

e are models used as the basis for construction of vulnerability indices so as to measure latent bles: reflexive and formative measurement models: In reflexive measurement model the latent :ructs exist in absolute sense. In this model, the index is a measure of an underlying construct h is thought to influence the indicators. Directional causality flows from construct to ators. As a result, change in a construct causes change in the indicators. Furthermore, the ators are evoked by the underlying construct and have positive and, desirably, high inter lations in empirical consideration. Since reflective indicators have positive inter correlations, ures such as, average variance and internal consistency are used to empirically assess the idual and composite reliabilities of the indicators (Coltman *et al*., 2008). A poverty index is most often an example of a reflexive model, whereby the construct, poverty, is thought to influence the various indicators chosen, such as literacy, expenditure, housing standard and ownership of assets (Leichenko *et al*., 2004). Conversely, the formative measurement model was the characteristic of positively correlated measure as a necessary condition in the construction of vulnerability index.

In a formative measurement model, all the indicators chosen by the researcher have impact on the vulnerability of the region, or a system, or an individual positively or inversely (Leichenko *et al*., 2004). In a formative measurement model, the index is measuring a construct which is influenced by the indicators. The latent constructs do not exist as an independent entity and all the indicators have an impact on vulnerability. For instance, HDI is a composite measure of human development in health, education and income (Coltman *et al*., 2008).

Therefore, vulnerability index is a formative measurement and the indicators chosen need not have internal correlation (ICRISAT, 2006). As Tarling (2009) stated latent constructs are variables which cannot be measured directly rather the measurement scale has to be constructed from fest variables. The author employed formative measurement model. The dependent variable e empirical estimation of this study was vulnerability which is the latent construct of the ative model and indicators which influence vulnerability are explanatory variables.

model variables for the analysis were categorized under the determinants of vulnerability s which encompassed exposure indicators (temperature change, rainfall variability and ency of extreme climatic events) and capacity and sensitivity indicators (farmland size, land ion, erosion rate and land policy, access to and use of farm input, land management training).

2.9.3 The Integrated Assessment Approach

The integrated assessment approach combines both socio-economic and biophysical approaches to determine vulnerability. The vulnerability mapping approach (O'Brien et *al.*, 2004) is another example in which both socio-economic and biophysical factors are combined to indicate the level of vulnerability through mapping.

Füssel (2006) argued that the IPCC (2001) definition of vulnerability, which conceptualizes vulnerability to climate as a function of adaptive capacity, sensitivity, and exposure, accommodates the integrated approach to vulnerability analysis. According to Füssel and Klein (2007), the risk-hazard framework (biophysical approach) corresponds most closely to sensitivity in the IPCC terminology. Adaptive capacity (broader social development) is largely consistent with the socio-economic approach (Füssel, 2007). In the IPCC framework, exposure has an external dimension, whereas both sensitivity and adaptive capacity have an internal dimension, which is implicitly assumed in the integrated vulnerability assessment framework (Füssel, 2007). Even though the integrated assessment approach corrects the weaknesses of the other approaches, o has its limitations. The main limitation is that there is no standard method for combining iophysical and socio-economic indicators. This approach uses different data sets, ranging socio-economic data sets to biophysical factors. These data sets certainly have different and nknown weights. Despite its weaknesses, this approach has much to offer in terms of policy ions.

integrated vulnerability assessment approach was therefore adopted to combine these socio omic and biophysical indicators so as to develop vulnerability indices on the basis of ative measurement model (Hahn *et al.*, 2009). Countries with higher levels of human knowledge are considered to have greater +adaptive capacity. Areas with greater frequency of drought affected the sensitive agricultural sector (yield reduction). Furthermore, increasing temperature and decreasing rainfall were identified regions more exposed to vulnerability to drought. On the bases of prior knowledge and vulnerability literatures, measurable vulnerability indicators were identified.

Therefore, the study adopted the integrated vulnerability assessment approach to study the vulnerability of rural households to climate change.

CHAPTER THREE

RESEARCH METHODOLOGY

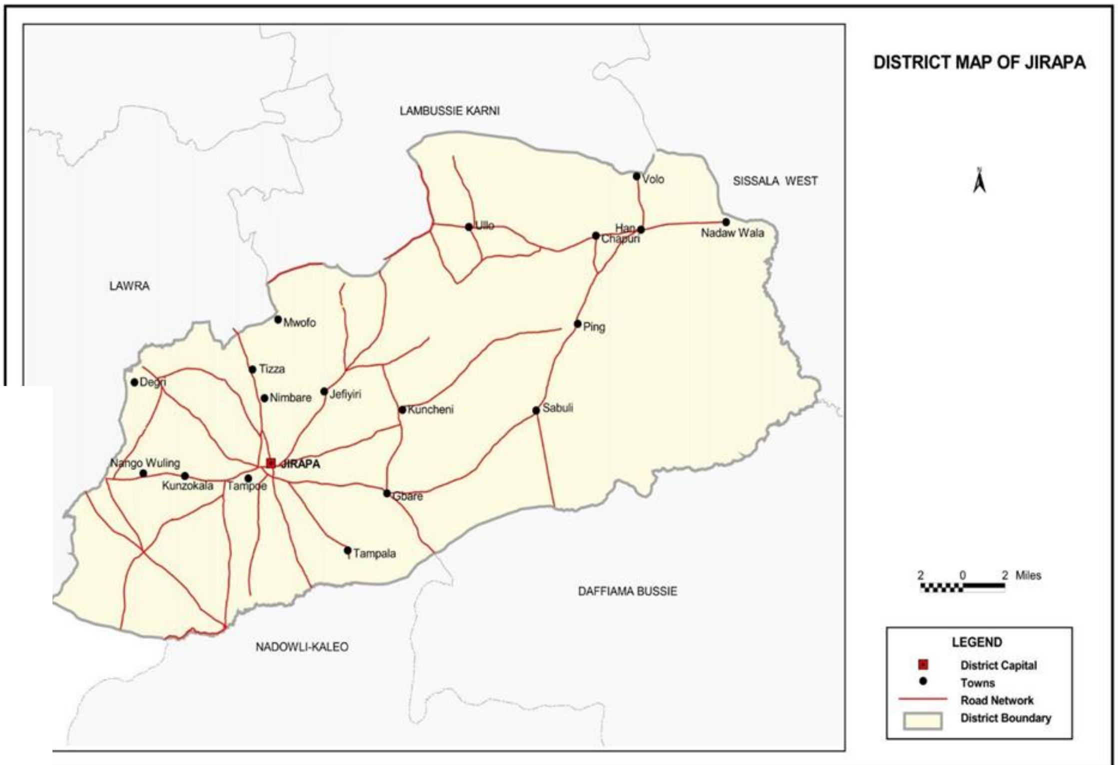
3.1 Introduction

This chapter presents the study areas which focuses on some physical, economic and social characteristics of the study area relevant to the study. It also discusses the methodology which consists of the research design, method/techniques of data collection and data analysis procedures oyed in the study.

'he Study Area

Jirapa District established by LI 1902 was carved out of the then Jirapa-Lambussie District as of a further enlarging and deepening of Ghana's decentralization processes in 2007. The ict is located in the north western corner of the Upper West Region of Ghana and one of eight cts in the region. It lies approximately between latitudes 10.25° and 11.00° North and tudes 20.25° and 20.40° West with a territorial size of 1,188.6 square kilometers representing ercent of the regional landmass.

Jirapa District is bordered to the south by the Nadowli-Kaleo District, to the north by the Lambussie-Karni district, to the West by Lawra District and to the east by the Sissala West District. The district capital, Jirapa, is 62 km away from Wa, the Regional capital. Figure 3.1 below shows the boundaries and some of the major communities and road network in the district.



e 3. 1: Map of the study area
ce: Ghana Statistical Service, 2014

Climate and Vegetation

The district is located in the tropical continental climate regime with mean annual temperature ranging between 28° C to 31° C which offers the opportunity for the development of solar energy. During the months of April/May-October the district experience a single rainy season induced by the moist monsoon winds with an intensity of 1,000-1,100mm per annum and humidity ranging between 70-90 percent but falling to 20 percent in the dry season (GSS, 2014).

The rainfall pattern within the season is irregular which makes it difficult to predict for any cropping year as long period of no rain often punctuate the wet season, leading to partial or total crop failures. The prevailing winds, the tropical continental air mass blowing from the North-East (Sahara), are cold, dry and dusty (Harmattan) usually between November to March. During this period of harsh weather, deaths caused by outbreaks of Cerebro-spinal Meningitis (CSM) and other diseases are common in the district (GSS, 2014).

The vegetation of the district is generally the Guinea Savannah woodland with light undergrowth and scattered medium sized trees. The major trees which are also the economic ones are shea, ıdawa, baobab and neem. Human activities such as bush burning, tree felling for fuel wood :harcoal burning, improper farming practices and the excavation of vast areas for sand and el all contribute immensely to destruction of the natural vegetation and therefore the onment. The district has no major forest reserves except some isolated pockets at Somboro, ong and Yagbetuolong along the Black Volta that are undeveloped. These tickets provide ective cover for streams in the localities mentioned above. The district is not well drained as ajor rivers are found except the intermittent tributaries of the Black Volta River. These are aa around Ullo, Bakpong near Baazu, Dazugri in Jirapa and Telenbe at Tizza (GSS, 2014).

e long dry season, these tributaries dry up leaving the district with no surface water catchment for domestic and agricultural purposes. The valleys of these tributaries are suitable for the development of small-scale irrigation dams and dugouts for dry season gardening, fishing and watering of animals, especially cattle. There are however, small-scale dams and dug-outs scattered throughout the district. Konzokala, Tizza, Jirapa and Ullo are some of the places where one can find dams and dug-outs (GSS, 2014).

Topographically, the landscape of the district is generally flat and low-lying with average height of 300 meters above sea level. There are few plateau surfaces ranging between 1,000-1,150 feet. These are found in Yagha and Jirapa (GSS, 2014).

3.2.2 Geology and Soil

The soil of the district is mainly sandy loam with underlying hard iron pans. There are however narrow strips of alluvial soils along the numerous dry valleys of the tributaries of the Black Volta r suitable for rice farming. It is important to remark that the sandy loam is susceptible to severe and gully erosion caused by surface run-off during the peak of the wet season. The spread erosion adversely affects not only the fertility of the soil but also contributes in silting ew dams in the district. A clear example is the Bulkpong dam in Jirapa (GSS, 2014).

rally, however, the sandy loam is very fertile and enhances large scale cultivation of ndnuts. There are large tracks of fertile soils in Somboro, Han and Mwankuriareas that can ort large-scale agricultural production. Also, there are gravel pits scattered all over the district oad construction. The extensive Birrimian formation and granite rocks largely found around ;a and Jirapa store considerable quantities of ground water which serves as the main source of water for sinking boreholes and hand dug wells. Geological survey carried out by a mining company in 1998 holds that the rocks contain gold deposits. Azumah Resources Ltd, an Australian based mining company is currently conducting exploration with the hope of developing a mine at Yagha.

3.2.3 Agriculture

Agriculture remains the main economic activity in the district with 67.1 percent of the people in the district engaged in agriculture, which is largely subsistence in nature. Very few farmers are engaged in large-scale production of cereals and legumes in Han and Mwankuri areas. Cash crops cultivated in the district are shea nuts, cotton, groundnuts and cashew (GSS, 2014).

The rearing of cattle, sheep, goats, pigs and poultry are mainly produced as a supplement to crop farming. A few farmers however engage in large-scale livestock production in the Han and Ping (GSS, 2014).

Rationale for Selecting the Study Area

research was conducted in five communities within the Jirapa District in the Upper West on of Ghana. The district was selected based on the fact that it has mode of production based arily on rain-fed subsistence farming, a high occurrence of poverty, an occurrence of weather mes such as droughts, and degraded farm lands within the district (Lawra District Assembly,).

rding to the Department of Agriculture (DOA) within the Jirapa district, the district is divided into twelve (12) MOFA operational zones. In consultation with the Department of Agriculture (DOA), the western belt was purposively selected for the study based on the degraded nature of farm lands, poor soil fertility and poor yield within this zone as compared to the rest of the zones.

3.3.1 Research Design

The study used cross-sectional research design by combining both quantitative and qualitative research methods. This study used a mixed methods design, which is a procedure for collecting, analyzing and “mixing” both quantitative and qualitative data at some stage of the research process within a single study, to understand a research problem more completely (Creswell, 2009). The goal of the mixed methods approach is to draw from the strengths and to minimize the weaknesses of both qualitative and quantitative approach (Johnson and Onwuegbuzie, 2004).

Cross sectional surveys are usually conducted as a one off activity. It gives on the spot accounts of a given concept or phenomena at a time. In other to give in-depth accounts, Strauss and Corbin ...0) advocated for the use of mixed approach with flexible techniques. According to Johnson *et* ...2007), mixed approach is the type of research that combine elements of qualitative and ...titative research techniques for the purpose of an indepth understanding. Arguing further, ...ss and Corbin, (1990) added that blending both approaches gives researchers the opportunity ...nefit from the advantages of both approaches in other to come out with a comprehensive in-...n study.

Sources of Data

...ssing the rural households’ agricultural land vulnerability to climate change require good-...ty data and/or information. Two main data sources were identified as relevant for investigating because they indicate the situations of vulnerability to climate change within the study area.

The first source of data is primary data. According to Robson (2002), primary data contributes to the researcher’s ability to address the most important issues in the research context, hence primary data was collected for this study. The primary data includes both biophysical and socioeconomic data collected through household survey supplemented with observation and interview techniques. The second source is secondary data which was collected from the Ghana meteorological services on records such as temperature, rainfall and extreme events which helped to gain initial insight into the research problem and acquire baseline information about the study site. Secondary data would also be collected from Department of Agriculture.

3.3.3 Sample Size

Sample size was determined from each community using probability proportional to size (PPS) od to make equal representation of households in each community based on Yemane 7).

iematically presented as: $n = N / 1+N(e)^2$ where

esignates the sample size the research uses,

designates total number of households in all the communities

esignates maximum variability or margin of error

(0.05), and 1 = designates the probability of the event occurring

nathematical formula provides a sample size of 180 which was proportionally distributed to

ve-communities using the following formula

$$ni = \frac{n \times Ni}{\sum Ni}$$

where n = determined sample size the research uses,

ni = households of the ith community, and

Ni = total households of the ith community (Table 3.1).

Table 3. 1: Number of total and sampled households of study areas

Selected Community	Zone	Total population	Total Number of households (sample frame)	Sample households
Kaani-Dallee	Tugo Zone	772	120	66
Tamparizie	Tampoe	199	22	12
Tuolung	Duori	230	38	21
Guo	Duori	630	94	51
Kul-Ora	Yaggah	351	54	30
Total			**328**	**180**

ce: Field survey, 2018

.1 Sampling Design

sampling design employed was both probability and non-probability sampling. The purpose mpling is to reduce the population to a reasonable size which ultimately reduces expenses and a research without sampling might consume too much time.

3.3.3.2 Sampling Techniques

Two major sampling techniques consisting of simple random sampling and purposive sampling were used in this study.

3.3.3.2.1 Purposive Sampling

Purposive sampling was used to select the district. The western belt of the district was also purposively selected based on the degraded nature of farmer's agriculture lands, poor soil fertility, poor yields and the erratic distribution of rainfall and temperature as compared to the other belts. According to Barbie and Mouton (2007) purposive sampling is a valuable kind of sampling used in exploratory research that gives the best chance to get rich qualitative data.

osive sampling was also used to select institutions likely to have the required information and rt knowledge with respect to the issue under investigation. Some of the institutions selected de Department Of Agriculture. Also the Meteorological department of the Upper West on was contacted to obtain the temperature and rainfall data of the District from 1961-2017.

.2.2 Simple Random Sampling

le random sampling technique was used to select five communities within the five zones in estern belt of Jirapa District. In the selection of the communities, all the communities within one were identified by serial numbers. Microsoft office excel was used to generate random ples for the selection of the communities. Simple random sampling was used to select communities within the selected operational area because it gives equal and independent chance of selection.

3.3.3.2.3 Convenience Sampling

Convenience sampling technique was used to select household's respondents within each five selected communities. This technique is used based on the fact that it is fast, inexpensive, easy and the subjects are readily available

3.3.4 Data Collection Method

meteorological data for Jirapa district were gathered from Ghana Meteorological Station for seven (57) year period to analyze temperature and rainfall trends, seasonal variations and dardized Precipitation Index (SPI) to compute drought duration, magnitude and intensity of tudy area.

ata from secondary sources include only meteorological, population and total household ber, the secondary data was found insufficient to answer all the specific research questions for tudy populations. Therefore, it was determined that primary data collection methods were the r data sources for this thesis. Accordingly, primary data were collected using household ey, field observation, and interview.

3.3.4.1 Household Survey

The household questionnaire survey was the main data source so as to determine the vulnerability of rural households' agricultural land to climate change. The household survey was used to collect a range of quantitative data on land size, farmland location, soil erosion rate, land fertility level, land exposure to flood, crop productivity on temporal scale, crop saving capacity for bad years and next cropping season, confidence on land tenure system, land certification, distance to agricultural input markets, input utilization, and about land management training. The questions were organized mostly into close-ended and supplemented with some open-ended forms.

3.3.4.2 Field Observation

The study also employed the method of observation as part of the data collection method. Observation is central to qualitative data collection as it provides first-hand and new information ·ding the topic under study. It also provides accurate and reliable data since this method of collection is less influenced by externalities but dependent on the observer (Robson, 2002). erable areas were documented through photographs by using digital camera. Field ·vations focused on bio-physical characteristics, land degradation, flood affected areas, water ırces and vegetation cover and land management practices.

.3 Interview

s Group Discussion, key informant interviews also constituted the techniques of data ction. The advantage of this approach is that it is capable of generating a lot of data within limited time. This approach also encourages participation and dialogue among local people and the researcher (Fliwk, 2006).

Also the research conducted some key informant interview with selected people with expertise, knowledge and experience to get an expert view of the issues. This method is particularly suitable when one needs to get in-depth information about the phenomena, hence one-on-one interaction with persons believed to be knowledgeable in the issue or have special knowledge (Krueger, 1998). The advantage of this method over the others is that it would give a fuller, comprehensive and reliable information about the phenomena.

According to Cargan (2008), Focus Group Discussion (FGD) is defined as a type of research method that involves bringing in a small group of subjects (typically 6 to 10 people) at one location, and having them discuss a phenomenon of interest for a period of 1.5 to 2 hours. Krueger (1988) added that focus group discussions give the researcher an insight to why people or group of people holds an opinion.

Techniques of Data Analysis

eerselvam (2004) asserted that after data is gathered, proper tools and techniques should be for classification and analysis of data. This study used both quantitative and qualitative data ysis methods. The former includes mathematical formulas such as simple linear regression), standardized precipitation index (SPI) and livelihood vulnerability index (LVI) supported descriptive statistics such as mean, frequency counts, percentage, maximum and minimum s of a distribution.

3.3.5.1 Simple Linear Regression (SLR)

SLR was used for analysing temperature and rainfall trends as it is the most commonly used method to detect and characterize the long-term trend and variability of temperature and rainfall values at annual time scale (Mongi *et al*., 2010). The parametric test considers the SLR of the random variable Y on time X. The regression model specified is:

$$Y = BX + C \qquad \text{Eqn 1}$$

Where, Y = changes in rainfall and temperature during the period; β = slope of the regression equation; x = number of years from 1961 to 2017; c = regression constant.

3.3.5.2 Standardized Precipitation Index (SPI)

The SPI was used to identify droughts during the period under consideration using annual rainfall data. The SPI is a statistical measure to detect unusual weather events making it possible to mine how often droughts of certain strength are likely to occur. The practical implication of lefined drought, the deviation from the normal amount of precipitation, would vary from 1 to another. It can be calculated as:

$$= \frac{X - \vec{X}}{\sigma} \text{ ………………………………………………………………………………Eqn 2}$$

efers to rainfall anomaly (irregularity) on multiple time scales; X represents annual rainfall e year t; ⇀ X is the long-term mean rainfall; and σ represents the standard deviation over the d of observation (McKee *et al*., 1993). Hence, the drought severity classes are:

e 3. 2: Drought category from spi

	Drought Category
-0.9	Mild drought
-1.00 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2.00 or less	Extreme drought

Source: Mc Kee *et al*., (1993)

Drought duration, magnitude, and intensity were analyzed based on quantified SPI values. Drought duration is the period between drought starts and ends expressed in months or years. Drought magnitude (DM) is the sum of the negative SPI values for all the months or years within the period of drought (McKee et al. 1993). Mathematically it can be expressed as:

$$DM = \sum_{j=1}^{X} - (SPI\ ij)$$

Where, j starts with the first month/year of a drought and continues to increase until the end of the drought (x) for any of the i time scales (the ith month or year from the observation period). Drought intensity (DI) is the ratio of the drought magnitude to the duration event, which can be ...essed as Mi/Li where Mi is drought magnitude and Li is the drought duration (McKee *et al.*, ...). Although drought analysis used both the monthly and yearly time scale, the yearly scale ...selected for detecting the long-term temporal patterns of drought in the studied area.

.3 Livelihood Vulnerability Index Using Functional Relationships

...ssessment of the vulnerability levels of the farmers was done using the livelihood vulnerability ...x (LVI) based on the household survey data. The indices were constructed using weighted ...ige approach to measure households' access to a set of livelihood assets and climate change exposures (Hahn *et al*., 2009). On the basis of the theoretical framework, indicators were selected for farmland quantity and quality indicators and climatic factors using expert judgment, observation. Vulnerability index (VI) was computed to analyze the vulnerability levels of rural households using a simple average approach. This method helps to assess households' access to land and related indicators. The vulnerability indicators measured were normalized as the ratio of the difference of the actual value and pre-selected minimum, and the range of maximum and minimum values of indicators for each indicator determined using the data collected from the sample households and secondary sources (Sullivan et al. 2002):

Vulnerability index value = $\frac{\text{Observed value} - \text{Minimum Value}}{\text{Maximum Value} - \text{Minimum Value}}$ ……………………………Eqn 4

This method of normalization takes the functional relationship between the predictor variable and vulnerability. ICRISAT (2006) identified two types of relationship: vulnerability increases with the increase (decrease) in the value of the indicator. In this type of relationship, the higher the : of the indicators, the more is the vulnerability. For example, the larger the change in erature, rainfall, and distance indicators, the more is the vulnerability of the place or the nunity to climate change risks. In this case, the variables have a positive functional ionship with vulnerability and hence the normalization was done using Eq. 4. For these types ariables, the average values are taken as observed values. For variables that measure iencies of events, the minimum value is set at 0 and the maximum at 100.

ndicators, which assumed to have an inverse relationship (adaptive capacity indicators) with erability, the inverse scoring technique was applied in the normalization of values for each ator by Eq. 5 based on ICRISAT (2006).

Inversed Index Values = $\frac{Maximum\ value - Observed\ Value}{Maximum\ Value - Minimum\ Value}$ …………………………………Eqn 5

Then the indicators were averaged by Eq. 6 to calculate the value of each component.

Average VI = $\frac{\sum_{i=1}^{n} Index}{n}$ ……………………………………………………………..Eqn 6

Where index refers to the indicator, represented by i, and n is the number of indicators. In this study the VI is scaled from 0 to 1; 0 denotes least vulnerable or no vulnerability and 1 denotes most vulnerable system.

3.3.6 Data Presentation

Tables, figures, and plates were employed as tools to help present data processed and analyzed so ı acquire easy to understand and systematic presentation of quantitative data that were cted. Plates were added to give visual appreciation of findings. In a similar vein qualitative was analysed and presented through description, quotations, narrations and interpreting the tions deeply and contextually so as to reveal the real situation on the ground.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

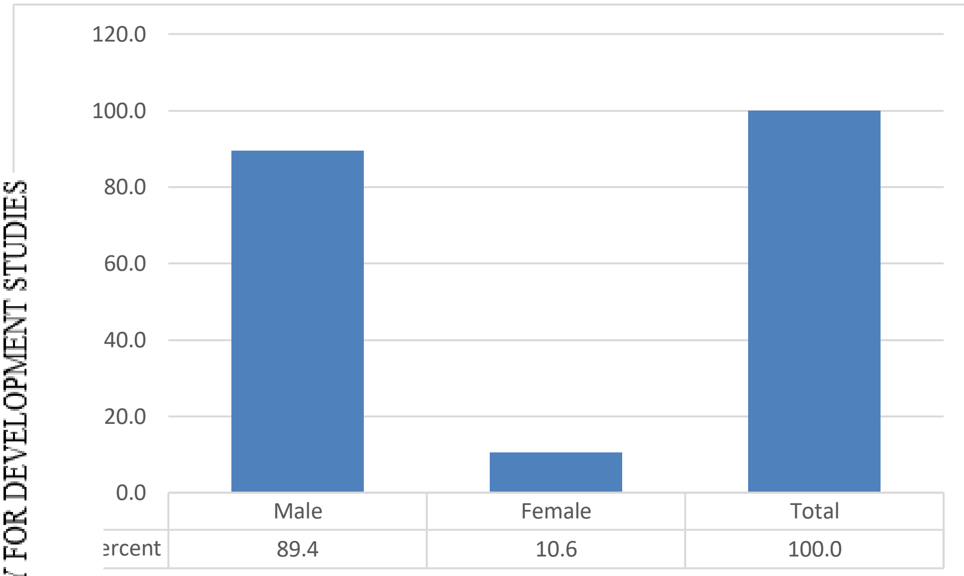
This chapter discusses results of data collected from one hundred and eighty (180) household's heads in the Jirapa District. The results are analyzed according to the thematic areas of the research objectives. These are: perception of rural households on climate change, an analysis the pattern of erature and rainfall between 1962-2017, Identification major climate change related hazards e study area and an analysis the levels of rural household's land resource vulnerability to ate change.

ocio-demographic and Occupational Characteristics of Respondents

Gender

e 4.1 indicates that about 89.4% (161) of the household heads in the study communities were s and 10.6% (19) were females. This result is consistent with Ghana Statistical Service report women and men in Ghana, which reported that in terms of gender of household head, male population contributes about 75.53% whiles female population contributes about 24.7% in rural area within the upper west region of Ghana (GSS, 2014). The study also confirms an analytical report out of the population and Housing census, which reported an 81.6% male headed household and 18.4% Female Headed households in the Upper west region.

From other studies, Gender of the household head is hypothesized to influence the decision to adopt changes. A number of studies in Africa have shown that women have lesser access to critical resources (land and labour), which often undermines their ability to carry out labour-intensive agricultural innovations (Gbetibouo, 2009). However, a recent study by Nhemachena and Hassan (2007), based on Southern Africa, finds that female-headed households are more likely to take up climate change adaptation methods.



4. 1: Distribution of Gender of Household Heads

ce: Field survey, 2018

Age

Table 4.2 indicates that 58.8% of the household heads in the study communities are within the age category of 50 years and above, 38.3% within 30-49years, and 2.7 % were within the age range of 15-29 years.

Table 4. 1: Age of Respondents

Age Group	Frequency	Percentage
15-29	**5**	**2.7**
30-49	**69**	**38.3**
50 and above	**106**	**58.8**
Total	**180**	**100**

ce: Field Survey, 2018

study assumed that a farmer who has been involved in farming activities for the past 20 years could have gained sufficient knowledge and experiences in farming activities and thus could demonstrate possible changes that have taken place in the area and in farming activities. Thus, heads of households whose age was below 30 were considered to have less knowledge and experiences in farming activities as well as fewer relevant observations in environmental changes (Gyampoh *et al.*, 2009). However, the lesser perception of climate change interms of temperature by younger householders (2.7 %) as against (58.9% of 50+ and above) may reflect less exposure to climate stimuli and reduced experience in terms of dealing with changing farm conditions and activities. As shown in table 4.3 this lesser perception by younger householders agrees with findings of similar studies conducted in farming systems from semi-arid Africa (Deressa et al. 2011).

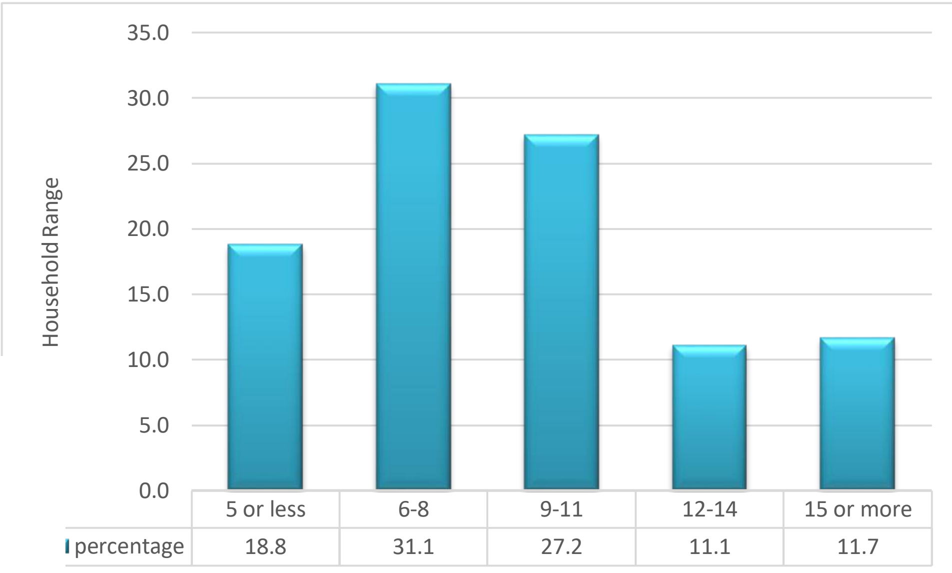
Table 4. 2: A cross Tabulation of age with perception on climate change

Age	**Perception of temperature**								**Total**	
	Increased		**Decreased**		**Don't know**		**Erratic in distribution**			
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
29	1	20	1	20	3	60.0	0	0.0	**5**	**2.7**
49	48	69.6	3	4.3	3	26.1	15	21.7	**69**	**38.3**
nd e	72	67.9	1	0.9	1	31.1	32	30.2	**106**	**58.9**
l	**121**	**67.2**	**5**	**2.7**	**7**	**3.9**	**47**	**26.1**	**180**	**100**

ce: field survey, 2018

Household Size of Respondents

Figure 4.2 presents the household size of respondents. The average household size within the study communities is 8.3. This is more than the average household size in Ghana which is four members and also higher than the average household size in the upper west region which is 6.5 Members (Schnitzer et al, 2014).

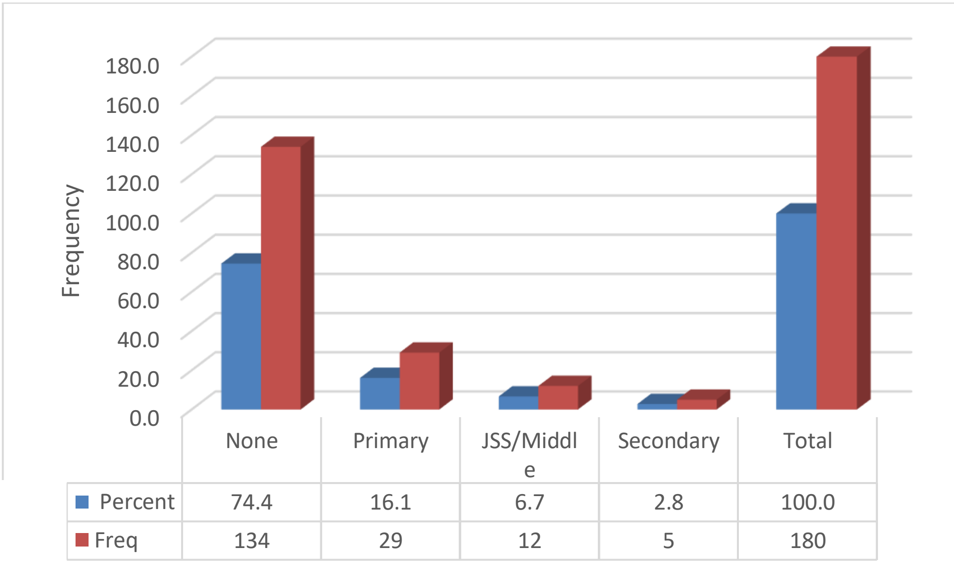


re 4. 2: Household size of respondents

ce: Field Survey, 2018

Educational Level

respect to educational status of the respondents, the data analysis showed that all the stages e educational ladder were represented in the sample. However, a large proportion of the sample, represented by 74.4% of the respondents had no formal education. 16.1% of them had primary education, 6.7% of them had secondary/middle school education whiles 2.8% of the household heads had secondary education as presented in figure 4.3 below. This result is consistent with Ghana statistical services report which reported that only 21% of household heads in Upper West region are literate

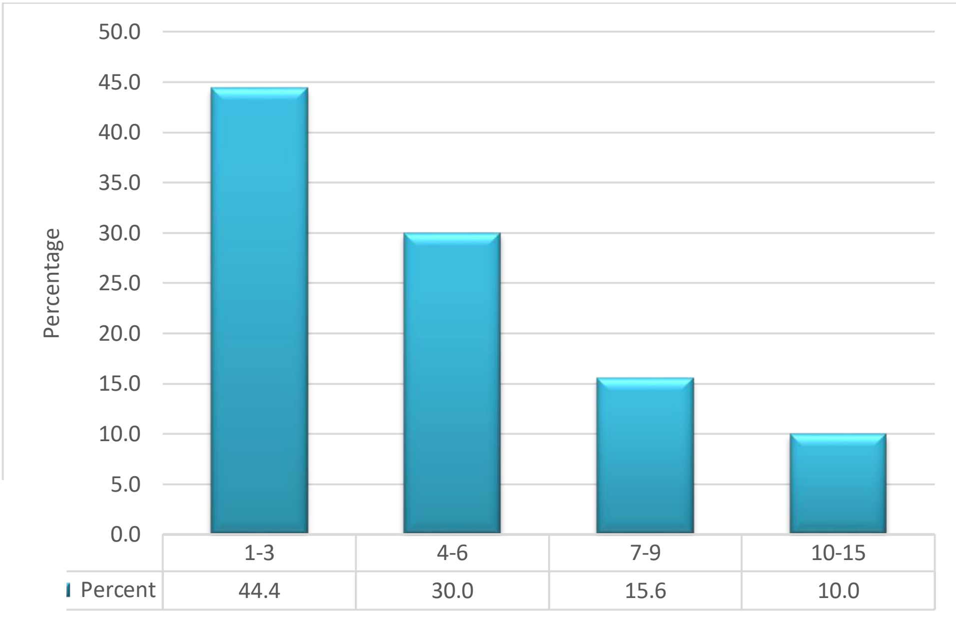


re 4. 3: Respondents level of Education

ce: Field Survey, 2018

Farm Land Size

ırding to MOFA, (2011) about 90% of farm holdings in the country are less than 2 hectares in Similarly, from figure 4.4, the study revealed that majority (44.4%) of the farmers in the study are small scale peasant farmers who only farm large enough to feed themselves as well as families and sell in case of surplus, with an average farm size of households in the studied communities been 5acres with minimum of 1 acre and maximum of 9 acres. The average is above the regional smallholder farm size average of 3.5ha (GSS, 2014).



re 4. 4: Household farm land size

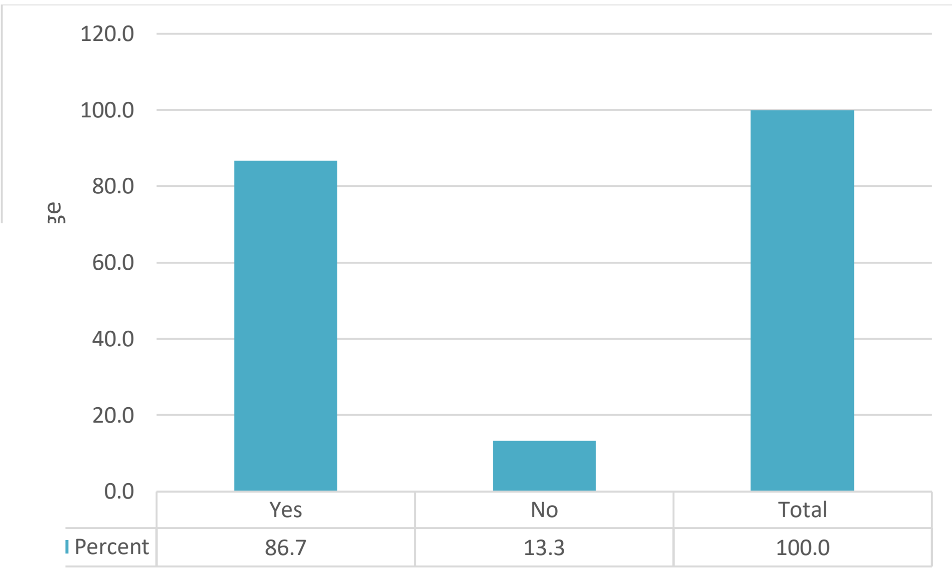
ce: Field Survey, 2018

ural Households' Perception About Climate Change

section of the thesis assessed households' perceptions of climate change at the community corroborated by meteorological data. Tests were undertaken for linear trend in maximum and num mean annual temperature and total annual rainfall for the Jirapa district using records from the Babile Weather Station. Descriptive statistics based on summary counts of the questionnaire structure were used to provide insights into farmers' perceptions of climate change. Annual climate variability may affect farmers´ view of climate change as a phenomenon, and this may in part explain interviewees´ differing responses and perceptions of climatic changes (Aasprang, 2013)

4.2.1 Household Perception About Changes in Temperature

As shown in figure 4.5, 86.7% of respondents perceived changes in temperature during the growing season in their life time whiles 13.3% perceived no changes in temperature pattern.



re 4. 5: Witnessed changes in temperature

ce: Field Survey, 2018

% of the respondents perceived temperature to be increasing, 2.9% observed temperature to ecreasing, whiles 23% observed an erratic pattern in temperature distribution. Stanturf *et al*. (2011) indicated that, mean annual temperature has increased and annual rainfall has reduced and highly variable in Ghana which confirms this study's findings.

Table 4. 3: Perception on Temperature change

OPTION	FREQUENCY	PERCENT
Increased	121	69.5
Decreased	5	2.9
Erratic in distribution	40	23.0
Do not Know	8	4.6

Source: Field Survey. 2018

eived changes in temperature were reiterated by three (3) Focused Group Discussions in the communities which ascertained the increment of temperature in their localities.

mer Stated that:

ve lived in this community all my life and I can say boldly that there have been an increase mperature over the past decade because at certain times that we used to have cold eratures but this days at same periods the temperatures are higher and very hot"

informant interviews gathered that, because of increasing temperature during the months of h, April and May, crops usually do not germinate well and there is always high prevalence of diseases in both humans and animals. Furthermore, streams, ponds and dugouts and rivers tremendously declined or dried up during the dry season because of high evapo-transpiration and low underground water table. Apparently, the key indicators of rainfall and temperature variability are the high rate of diseases and pest, poor germination, withering of crops, change in the planting time/months for the major crops and the disappearance of some fauna and flora (IPCC, 2014).

In terms of the pattern of perception to climate change, it is quite different from the study conducted in semi-arid Tanzania by Mongi *et al*. (2010) as it pointed out different perceptions among social groups in terms of level of education, location, age and gender. In the case of this study, interview and discussion results confirmed that there is no varied understanding on the trends of temperature and rainfall by level of education, age and gender in the study site. In terms of perception, the local communities unanimously agree that the climate is continually changing and getting worse and worse from time to time. In the study site, it is commonly agreed that the temperature is getting much hotter across times. Such a situation therefore results in poor performance in agriculture and food security efforts.

Household Perception About Changes in Rainfall

ıseholds' perception to precipitation changes was analyzed based on their local observations n asked "have you witnessed changes in rainfall", 88.9% (160) of respondents said yes they observed changes in rainfall pattern whiles 11.1% of respondents said no they have not :ved changes in rainfall as indicated in figure 4.6 below.

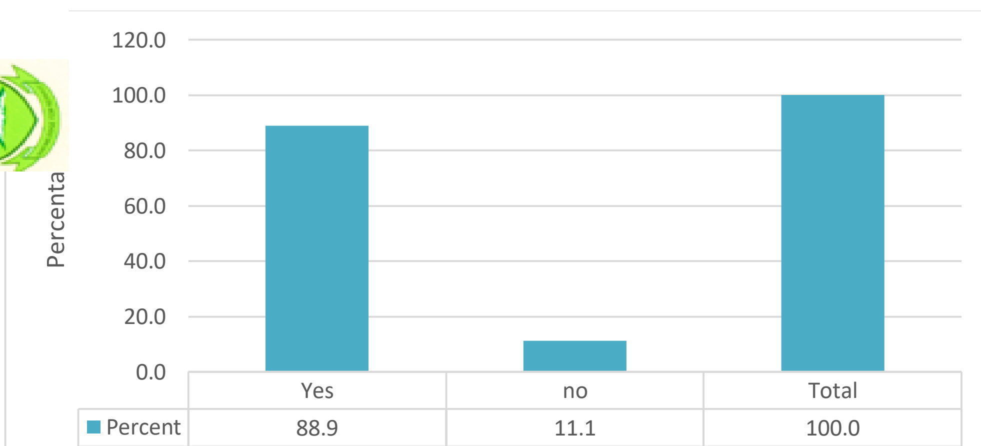
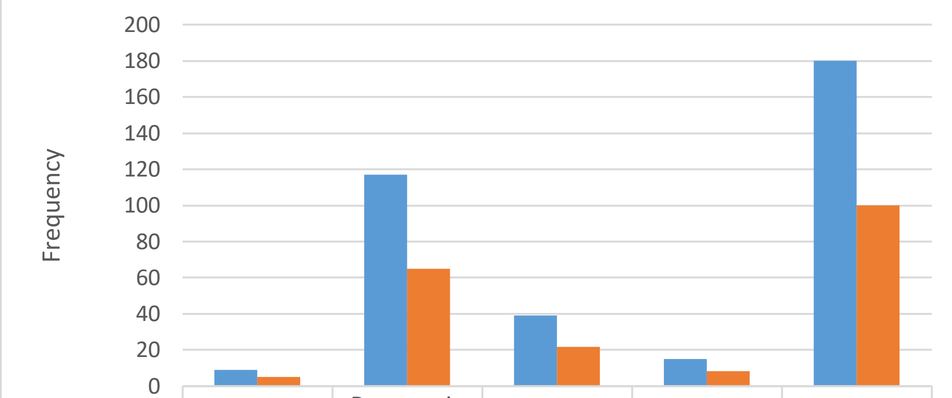


Figure 4. 6: Respondents Who has Witnessed Changes in Rainfall

Source: Field Survey, 2018

Among respondents who observed changes is the rainfall pattern, 65% (117) respondents perceived a decrease or reduction in rainfall amount in the community. 5% perceived an increase while 21.7% perceived the rainfall pattern to be erratic in distribution as shown in Figure 4.7. This study is in tandem with Assan *et al*. (2009) who indicated that the pattern of rainfall is erratic in Northern Ghana and it changes from one year to another, with a progressive decline in the average level of rainfall coupled with a gradual increase in temperatures. The 88.9 % of the surveyed households who have already perceived changing precipitation pattern were asked how pitation in itself has changed, 52.8 % of the households said that rains sometimes come earlier expected and at other times delay, 45.6 % of the households noticed that rains delay in coming ›nly 1.7% said that rains come earlier than expected. This finding is supported by a study by ;alawe (2013), conducted in the southern part of Tanzania, which suggested that changing ıtic conditions have resulted in delays and fluctuations in rainfall onset.

(2013) noted that, the rainfall patterns in Ghana of late do start late and then when they do e, they are shorter couple with intense rainstorms. Bryan *et al*. (2013) suggested that the er's perceptions of long-term decreases in rainfall from the household survey are actually based on their experiences with rainfall variability, and particularly changes in timing and distribution of rainfall.



	Increase	Decrease in rainfall amount	Eratic in distribution	Donot Know	
Frequency	9	117	39	15	180
Percent	5	65	21.7	8.3	100

re 4. 7: Perception about how rainfall has changed

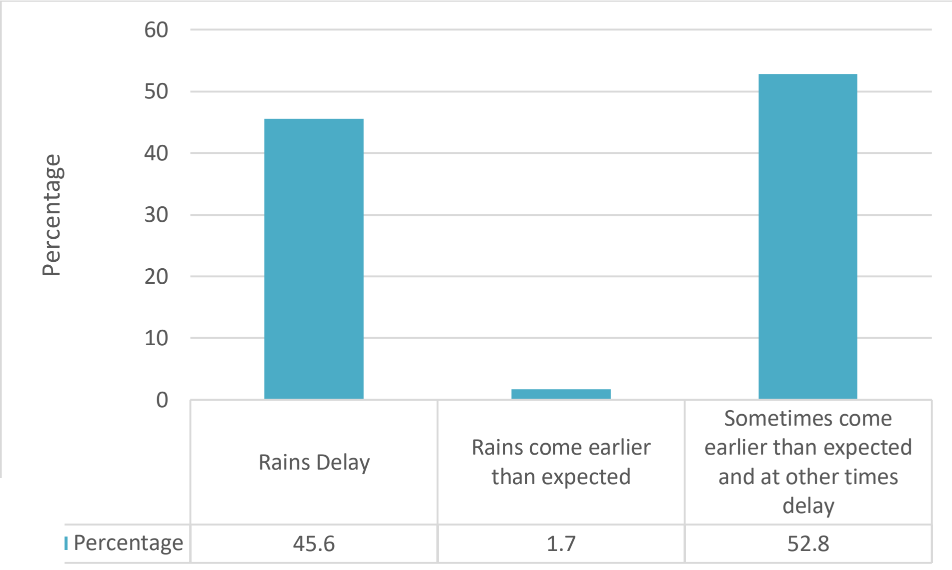
rce: Field Survey, 2018

ıdy conducted by Mtambanengwe *et al*. (2012), observed that, 95% of farmers in that study ated that they have observed changing trends in weather patterns and singled out increasingly ɘdictable trends in rainfall distribution as the major change they have witnessed during their me. This observation by Mtambanengwe *et al*. (2012) is in tandem with this present study. ‹ey indicators of a varying climate, according to a focus group discussion were related to their farming activities. Drought, floods, reduction in rainfall amount, delay and erratic rainfall regime, hot temperature and availability of pest and diseases are the major indicators of climate change perceived by farmers. Amongst indicators identified, household survey respondents and Key informants both labeled drought and erratic rainfall as the major indicators of climate change in the district. A discussion at an FGD held that rainfall was the most unreliable and tremendously uneven and hence exceedingly unsatisfactory among the indicators. Similar studies in other parts of the world showed that 99% of respondents indicated they witnessed the irregularity of rainfall amount and distribution during the main rainy season (Nigussie and Girmay, 2010).

An elder (73 years old) shared his experience regarding the variability and erratic nature of rainfall as follows:

"I have lived in this area since my childhood and have seen a lot in my life. One major challenge for us as a farmer is shortage and unpredictability of the rain seasons. Things are becoming less ble and unable to predict what will come next; rain starts late and ends very early; prolonged lays lasting even for weeks during the main rainy season are common and intensifies the ence of crop pests and diseases. In short, we are farming under such uncertainties … we trust God and planting even in the times of no good rain"

testimony is in line with the statistical output of meteorological variables where temperature ainfall variability have increased through time. Besides, the lifetime experience of farmers ding the early cessation of main rainfall is in agreement with output of the regression analysis e statistically non-significant (p=decreasing trend for annual rainfall (which is very vital in ultural production system) was found.



re 4. 8: How has rainfall season in itself changed

ce: Field Survey, 2018

Analysis of Temperature Variability in the Study District with Records from GMS

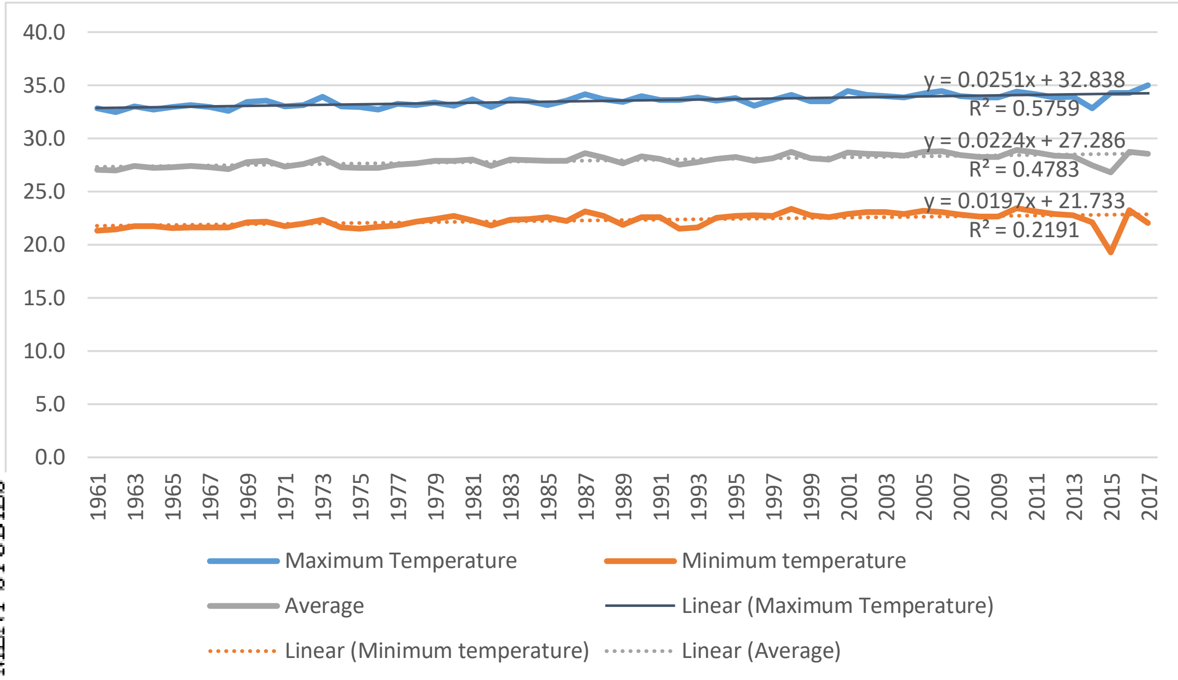
esults of the meteorological data showed that annual temperature in the study area had been creasing trends for the last five decades (1961–2017). Figure 4.9 presents the maximum, num and average temperature trends of Jirapa District. The estimated trend line for average al temperature is y = 0.0224x+27.286. The trend line has a positive slope indicating that the average temperature has increased by 1.28 °C in the past 57 years at a significant rate (p=0.01). Temperature rose by 0.224 °C per decade indicating that there was faster rate of temperature rise in the period (1961–2017).

Table 4. 4: Regression statistic results for Temperature and Rainfall within the district.

Variable	R-Square	p-Value	Statistically Significance
Maximum Temperature	0.576	0.0063	Yes
Minimum nperature	0.219	0.095	No
:rage nperature	0.478	0.01	Yes
nfall	0.021	0.16	No

e 4.4Source: Field Survey, 2018

maximum and minimum temperature trends were also calculated using simple regression tion for the mentioned period. The regression line for Maximum Temperature was Y=0.0251x .838 and Y=0.0197x + 21.733 for that of Minimum Temperature. It was found that both of them showed increasing trends in the study area. Maximum Temperature increased faster while the minimum temperature increased gradually.



re 4. 9: Maximum, Minimum and Average Temperature trends

·ce: field survey, 2018

example, the former increased by 1.43 °C at a significant rate (p=0.0063) while the later ased by 1.12 °C at a non-significant rate (p=0.095) in the past 57 years. In decadal time scale, naximum temperature rose by 0.251 °C and the minimum increased by 0.197 °C. This ging pattern is similar with other empirical findings done in Dabat and Simada Woredas ıome, 2015).

4.2.4 Analysis of Rainfall Variability in the Study District with Records from GMA

Evidence of rainfall variability in the Jirapa district is provided by climatic records from 1962–2017 obtained from the GMA. The records indicate that, there have been some hydro-climatological changes within the study district and region at large. Figure 4.11 shows that rainfall variability has been detected in the Jirapa District. For instance, the district recorded the highest rainfall amounts of 1542.8 in 1963 followed by a succession of erratic rainfall patterns until 1986 where the lowest rainfall amount of 524 mm was recorded.

irming this study results 1983, 1984, were also identified by Antwi (2012) as years with ght seasons. This reduction in rainfall confirms the field observations of household's/ ondents' perception that the rainfall regime has become highly variable and erratic. According su (2013), Ghanaian precipitation patterns are not easily predicted with years of drought being wed closely by years of flooding, both equally as destructive to crops and both leaving a wake mine and reliance on foreign aid. The research findings of a reduced, erratic and short rainy on confirm other researches which suggest significant decreases in rainfall amount in Sub-ran Africa, including Ghana (Boko *et al*., 2007). The mean annual rainfall in the Jirapa District for 57years was 1034 mm. This mean annual rainfall (1034mm) is not sufficient for crop production. Also, the amount of rainfall is not fairly distributed in the growing months. In terms of farming activities, it is not simply the amount of precipitation that matters. In fact, average rainfall may be less important than the dispersion and distribution of rainfall during the growing season (Fussel, 2007).

The meteorology data for the period 1961–2017 indicate that the overall rainfall amount and distribution varied from time to time in the Jirapa District. The range of total annual rainfall has become 524–1543 mm with an annual total average of 1034mm. The Jirapa District has experienced unimodal rainfall pattern. The rainfall occurs mostly Mid-June to Mid-September. Over 78 % of the rainfall was received in this season (see Figure. 4.10 and Table 4.5).

Table 4. 5: Statistical Analysis of Daily precipitation data

Month	average	stdev	Skew
Jan	3.5	12.4703	4.105108
[illegible]	7.3	17.8452	3.346728
rch	31.0	27.8284	1.382169
il	80.4	42.0159	0.723765
y	125.8	40.6171	0.165247
e	137.6	58.2530	0.560588
y	158.9	60.8198	0.826237
g	202.0	82.2370	0.492452
t	195.7	62.5793	0.298153
[illegible]	79.4	51.8472	1.505855
Nov	9.0	13.7732	2.51135
Dec	4.1	11.0257	2.650725

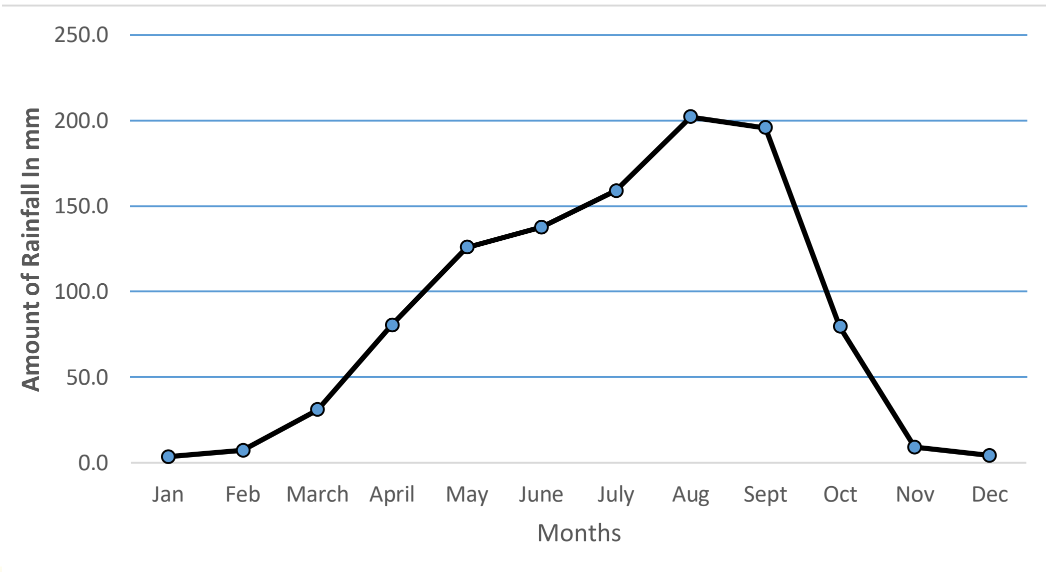
Source: Field Survey, 2018

The standard deviation is one way of summarizing the spread of a probability distribution; it relates directly to the degree of uncertainty associated with predicting the value of a random variable. High values reflect more uncertainty than low values. Table 4.5 clearly reveals that August (82.2370) and September (62.5793) in the Jirapa District had the highest standard deviation. The highest amount of average monthly rainfall was recorded in August (202.0 mm) followed by September (195.7), and the lowest was recorded in February (3.5 mm) followed by December (4.1 mm). From the analysis, it was observed that rainfall is at its peak between June and September Figure 4.10).

month to month precipitation changes are considerable across the years. When the standard ation values are examined, it is observed that the values are higher in June, July and August other months (Table 4.5). This relation between the standard deviation and the average values ates that the deviation from the normal distribution cannot be ignored. To test whether the al rainfall data follow a normal distribution, the skewness and kurtosis were computed. ness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Positive values for the skewness indicate that the data are skewed to the right. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution.

Hence the annual rainfall distribution under consideration did not follow normal distribution (See Figure 4.10). The simple regression results computed based on Mongi *et al.* (2010) indicate that there is momentous inter-annual variability of rainfall and slight rate of decline in the Jirapa District over the past decades considered in this study.

It is clear from Figure 4.11 that the mean annual rainfall distribution is gradually declining from time to time. However, long-term rainfall changes in the selected time span, appeared to decrease at a non-significant rate (R^2 = 0.066).



igure 4. 10: Long term monthly average rainfall distribution in Jirapa istrict (1961-2017)

Source: Field Survey: 2018

The main problem in terms of rainfall distribution is the timing (late onset and early cessation) and falling in intense episodes in very short duration. The long-term reduced amount of rainfall calculated using SLR for the observation period indicates that the rainfall declined by 516.99 mm. These results are in line with other empirical research findings conducted in Ethiopia and other nations of Africa. For example, a study in Debark Woreda of northwest Ethiopia indicates that the rainfall has shown a decreasing trend (ACCRA, 2011). The study made in Tanzania also supported this finding which declared decreasing trends of rainfall for the last 35 seasons from 1973/74 to 2007/08 (Mongi *et al.*, 2010). Similarly, studies in South Africa (Gbetibouo, 2009) and in the Sahel region of Arica (Mertez *et al.*, 2008) also found decreasing rainfall trends over the past consecutive decades.

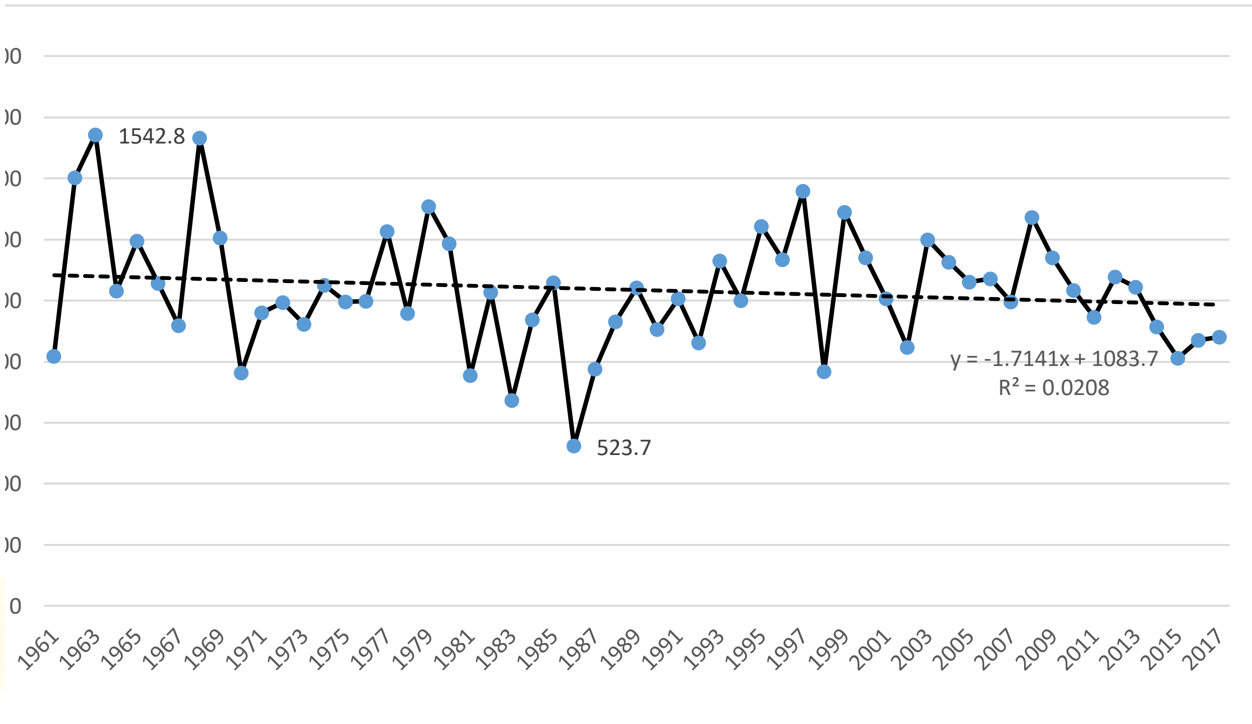
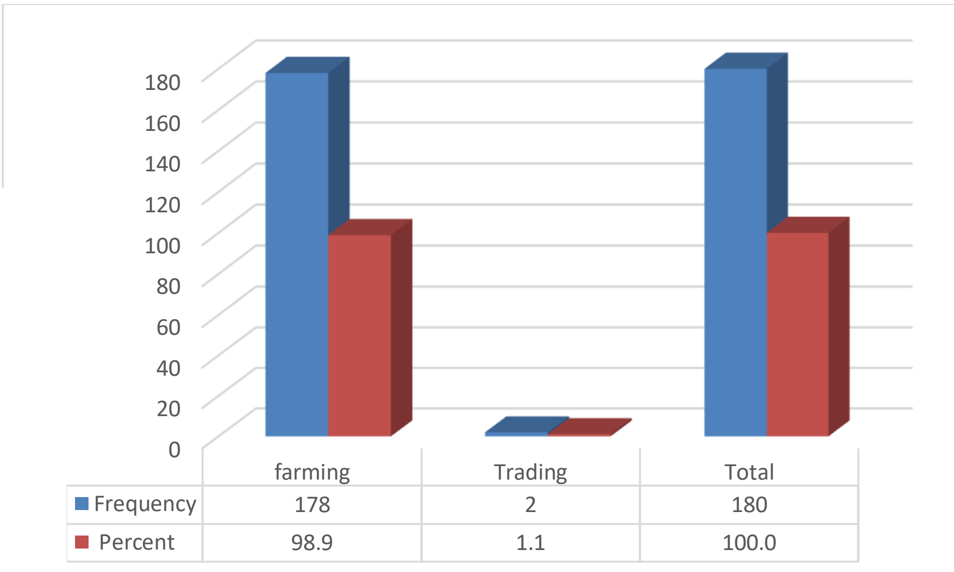


Figure 4. 11: Long term mean rainfall trend in Jirapa district (1961-2017)

Source: Field Survey, 2018

4.3 Livelihood Strategies and Climate Change Related Hazard in the Study Area

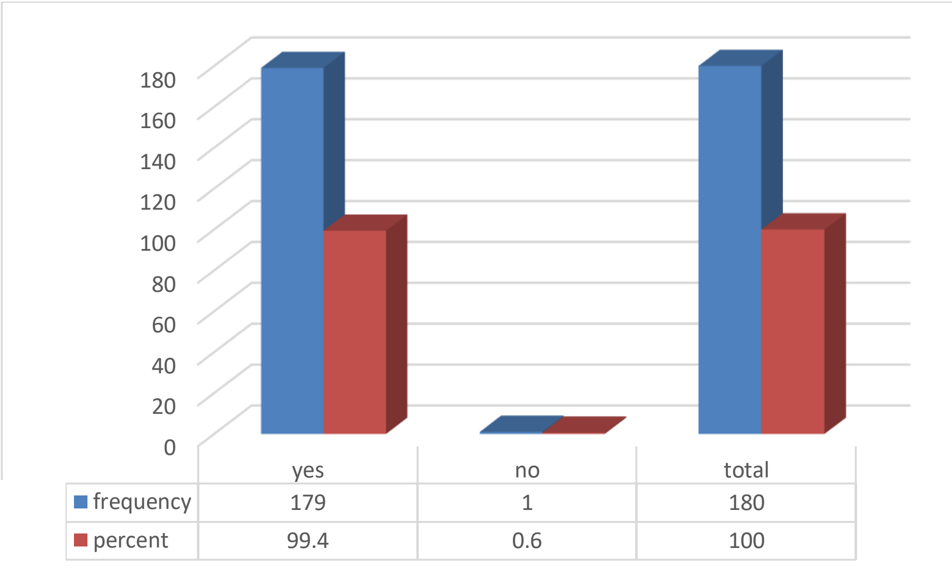
As it is shown in figure 4.12, 98.9% (178) of the households in the study communities confirmed that, their major source of livelihood is farming whiles only 1.1% (2) selected trading as their major source of income. 99.4% (174) indicated that the cultivate crops whiles 93.9% (169) also indicated that the rear livestock. The main crops grown are maize, cowpea, rice, millet, and groundnut. As shown in table 4.6 below, the major animals reared are goats and sheep.



re 4. 12: Livelihood Activities

rce: Field survey, 2018

Gecho *et al.* (2014) reported that the inherent seasonality and year-to-year variability of agricultural enforced the rural poor to engage in livelihood diversification which is consistent with this present study. This research is also in tandem with Gebretsadik (2012) who observed that, rural households obtain livelihoods from agriculture, rural labor market and self-employment in rural nonfarm economy, and others through migrating to towns, cities and other countries.



re 4. 13: Household heads who cultivate crops

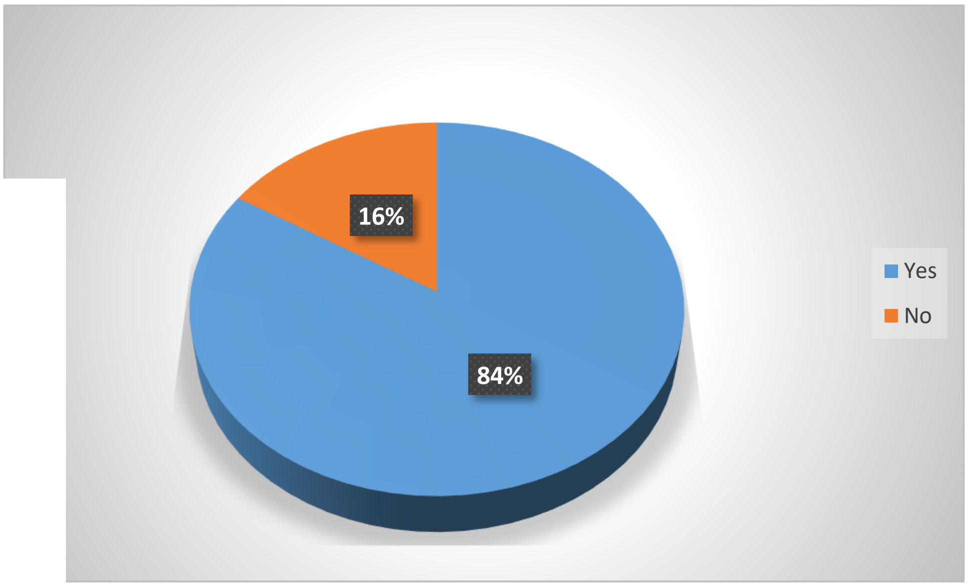
ce: field survey, 2018

e 4. 6: Types of animals reared

	FREQUENCY	PERCENTAGE
TLE	6	3.4
EP	56	32
AT	107	61.1
PIG	6	3.4
TOTAL	175	100

Source: Field survey, 2018

Changes in climate are associated with numerous hazards, it can increase poverty or even reverse development successes already achieved (ADB, 2011). 84% of the respondent's, as shown in Figure 4.14, in the study communities agreed that they are experiencing drought. Majority of respondents complained of drought because about 98.9% of the people in the study area are farmers and their agriculture is rain fed. This study is in line with a study conducted by Fosu (2013) who reported that 77.80% of respondents conceded that drought was getting worse over the years.



re 4. 14: Respondents who have witnessed drought

ce: Field Survey, 2018

ght is also a catalyst to increased food shortage because a reduction or no rains will result in crops failure leading to food shortage. During a focused group held in Guo community, the people lamented soo much over the 2011/2012 droughts because it had many devastating impacts in their lives. From a historical perspective, farmers also recalled the 1983 drought, a severe drought that had a devastating effect on agriculture and the natural vegetation experienced in the country and across many neighboring West African countries. They recalled experiences of total crop failure, disruption of livelihoods, food insecurity crisis and survival on international food aid.

This finding on the occurrence of drought conditions has been suggested in other studies that climate change will result into increased drought conditions particularly in Africa and the impacts will be severe due to increased reliance on rain-fed agriculture with only a limited capacity to invest in coping and adaptation strategies (IPCC, 2007).

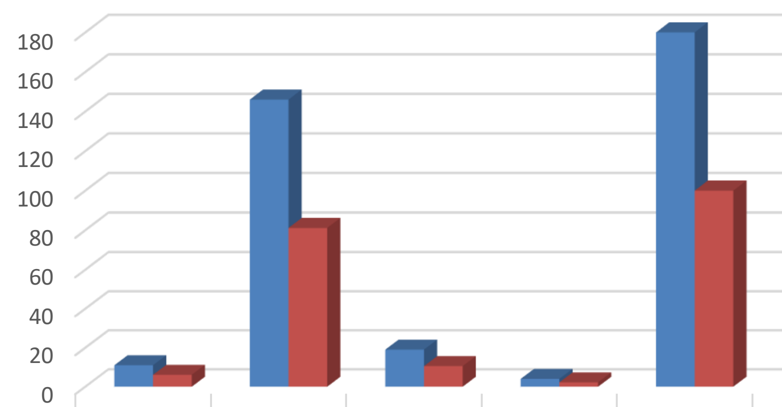
Increased climate variability especially in the case of drought lowers agricultural production, with different impacts on natural, physical, social, and financial capital (ADB, 2011). 97.2% of the respondents also claimed that they have experienced new pest occurring in their communities ...es 72.2% of respondents also said that they have witnessed more weeds growing. The fall ... worm was the major pest that was identified by farmers to be the most devastating to their ...e fields in 2017.

...mer in Kaani-Dallee community during a focus group discussion said:

...he past 10 years we have not noticed any new type of pest invading our farmlands and even ... had noticed any they were easily controlled. But for last year we had a massive invasion of ...all army worm which destroyed several hectors of our maize crops. Everything was gone in ...atter of days and all our investments into maize production went down the drain. I and my ...y had a very tough season last year and bearly had food to eat. I think that eighter changes in the weather patterns can be blamed for the presence of the fall army worm or our Gods have placed a curse on us."

Livestock production is particularly hampered by the unavailability of pasture/grass for animals to graze, inadequate water for animals to drink and more importantly diseases have been killing animals in recent times. 90.6% have complained that they have lost their livestock over the years with which 81.1% attributed it to pest and diseases and 10.6% also attributed it to poor pasture.

This study supports the findings of Addisu *et al.* (2016) who made it clear that the severity and distribution of livestock diseases and parasites is conditioned by climate change. A study by FAO (2006), indicated that about 83.1% of households noted livestock farming was most often disrupted by climate change which supports the current study. The quantity and quality of livestock feed stuffs such as pasture and forage can be indirectly affected by climate change (McCarthy *et al.*, 2001) significantly influencing farmers` livestock selection choices. Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance ylinson, 2008).



	Inadequate Water	Pests and Diseases	Poor Pasture	Inadequate Labor	Total
Frequency	11	146	19	4	180
Percent	6.1	81.1	10.6	2.2	100.0

Figure 4. 15: Causes of livestock lost

Source: Field Survey, 2018

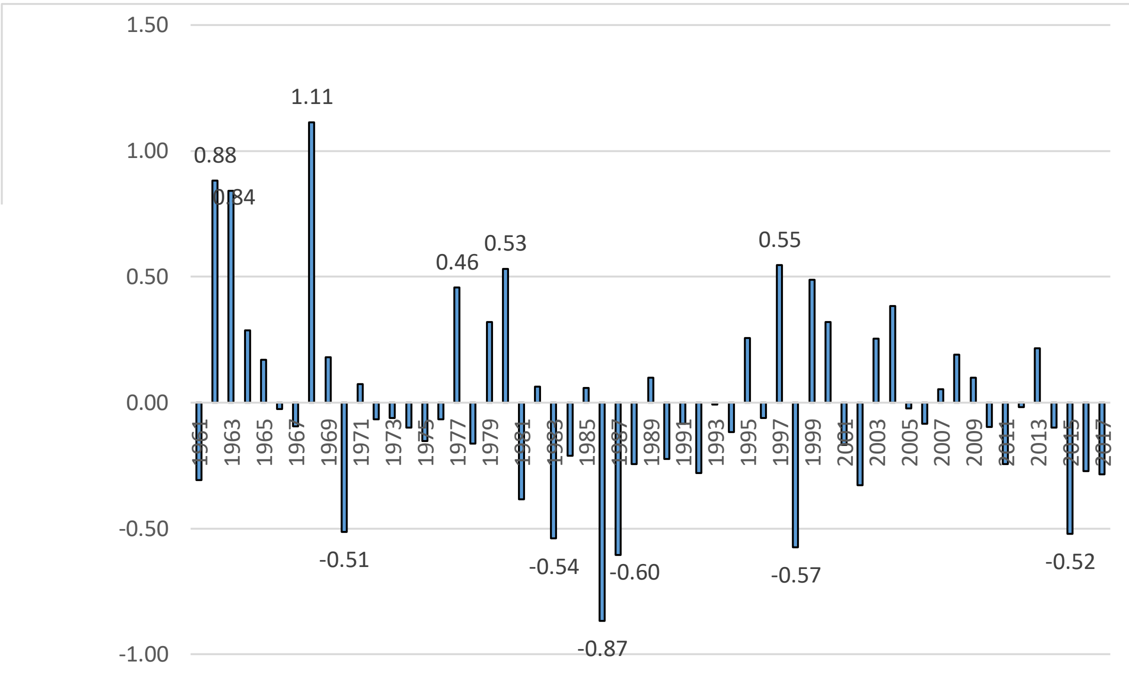
4.4 Meteorological drought analysis (1961–2017)

Drought can be marked by precipitation deficiency that threats the livelihood resources and overall development efforts of nations and specific places through worsening water shortage. Therefore, analysis of drought duration, magnitude and severity is highly demanded for designing appropriate mitigation and adaptation strategies. Standardized precipitation index (SPI) was used for analyzing the long-term drought pattern in the Jirapa District (See Figure 4.16). A drought event occurs whenever SPI values are continually negative and ends when the values become positive. Drought has a duration defined by its commencement and termination. The positive sum of the SPI values for all the months within a drought event is termed as drought magnitude. The intensity of drought event is defined as the ratio of event magnitude to its duration.

It is clear from Figure 4.16 that the rainfall is described by alteration of wet and dry years in a dic pattern. Out of the 57 years, 33 years (57.89 %) recorded below the long-term average al rainfall amount whiles 23 (40.35%) years recorded above-average. Only the year 1993 ved equal rainfall amount with the long-term average rainfall. Most of the positive SPI values rred between 1962 and 1969 and also between 1995 and 2004. Consecutive negative SPI es occurred from 1970 to 1976 and 1981 to 1992. The 1986 rainfall amount was the lowest d in the observation period with SPI value −0.87 whiles the year 1968 recorded the highest int of precipitation with an SPI value of 1.11.

SPI result indicates that long-term drought characteristic in the Upper West Region was found 7.89-magnitudes and 0.66-intensity in the 12 years of duration implying high exposure of agricultural land to intense drought conditions in the Jirapa District.

The drought in the year 1986, 1970 and 1983 were the longest droughts (12, 10 and 10 months respectively) with a magnitude of 10.39, 6.94 and 6.54 respectively in the district. However, in terms of drought intensity, 1990 drought was the severest with an intensity of 1.06. This goes to imply that a longer drought period may not necessarily be the most severe. Dry spells impact greatly on agriculture (crop production) than more intense drought/flood occurrences. This finding is in agreement with Schipper *et al.* (2007) who reported that small droughts can have bigger impacts than bigger droughts. This is because dry spells are erratic and can happen several times and at critical periods of the rainy season leading to severe plant water stresses and reduced yields.



re 4. 16: Standardized precipitation index for Jirapa district (1961-2017)

ce: Filed Survey, 2018

From the foregoing, the SPI in decadal years within the study area, revealed that the corresponding value of SPI tend to be on mild drought as observed from the values within the study area to be 0 to -0.90. (Mc kee *et al*., 1993)

4.5 Households' Vulnerability to Climate Change with Respect to Agriculture Lands

Agricultural land is the main measurement of vulnerability situations of the rural households in this study. In this section, the Livelihood Vulnerability as developed by Hahn *et al*. (2009) was adopted and modified to analyze the livelihood vulnerability levels of rural households to climate change with respect to climate change impacts on agriculture lands. The major indicators selected were farmland size, soil erosion severity, land fertility level and crop yield based on households. Additionally, seventeen (17) other indicators (Totaling 21 indicators) were selected for vulnerability assessment. The LVI was computed for the five study communities (Guo, Tamparizie, Tuolung, Kul-Ora, and Kaane-Dalle.

The 21 indicators were grouped into three IPCC components that make up vulnerability namely, ısure, Sensitivity and Adaptive Capacity; which are termed Contributing Factors (CF). IPCC ition of vulnerability, which takes into account exposure, sensitivity and adaptive capacity is nted in the vulnerability triangle as shown in figure 4.17, it ranges from 0 (low contributing r) and 1 (high contributing factor).

e 4.17, Table 4.7 and Table 4.8 illustrate that, the households' agricultural lands are found to ıcreasingly vulnerable at 0.58 vulnerability index. Field observation asserts that the ıysical contexts have already made the households more vulnerable in terms of this livelihood ırce.

4.5.1 EXPOSURE

The exposure of a system is determined by the amount of stress that impacts the unit of analysis. Exposure can be represented by a change in magnitude, frequency and duration of extreme climatic events (such as droughts, floods, storms, etc.), climate variability or long-term climate patterns such as increasing temperature and decreasing precipitation to which farmers' livelihood assets like land, forest and water resources are exposed (Brooks, 2003). Accordingly, exposure indices were constructed using changes in temperature, rainfall, and frequency of extreme events for the study locations. Most of the farmland in the district is rainfed, and declining precipitation in recent years and increasing drought can impact livelihoods through the impact on agriculture (Sujakhu *et al.*, 2016).

The vulnerability triangle indicates that Guo and Tuolung communities are more exposed to climate change and extreme events with LVI of 0.53 for both communities and this was slightly followed by Tamparizie (0.49) whilst a low exposure status was determined in Kul-Ora at 0.45 exposure index value. When the exposure indices are compared indicator-wise among different nunities, Households within Tuolung community indicated that they had witnessed floods a vulnerability index of 0.71 and this might be the reason why Tuolung community is among rst two communities which are highly exposed to climatic extreme events.

ung community is also located about 2.14 away from the Black Volta whiles their farmlands bout a 50-100m away from the Black Volta. The closeness of the communities' farmlands to Black Volta makes them more vulnerable to the impacts of floods. Plate 4.4 below shows a le view of the Black Volta which passes through Tuolung community with farmlands sighted close to the water. All the communities recorded the same LVI value for average exposure by temperature (0.43) and average exposure by rainfall (0.47) this is because the study communities are under one meteorological center and do not have independent climatic data records. Again, climatic extreme events found to be more frequent in Kul-Ora (0.67) followed by Guo (0.66). The vulnerability indicator value for drought experienced is higher in Tuolung community with a LVI of 0.9 followed by Guo and Kaane Dalle communities which recorded the same LVI value of 0.89. All the Communities are observing negative impacts of drought and extreme events on natural resources such as farmlands, pasturelands, water sources, and vegetation's. One government official at Office of Agriculture noted the problem as:

"The production potential of the land is going down, due to shorter rainy seasons, recurrent droughts, intense rainfall events which cause severe erosion, and overgrazing. Pests and diseases infestations also has posed tremendous damage on cultivated crops"

e 4. 1: Google Image of farmlands and Black Volta at Tuolung

rce: Field survey, 2018

Although agricultural land is highly valued by the society, it has experienced persistent pressure and stresses from a range of direct and indirect socio-economic driving forces. Indeed, they are severely affected by climatic and environmental changes, leading the studied household's dependent on these resources, more vulnerable to poverty and food insecurity. The impacts of future changes will be felt particularly by these communities given that our environment has faced with risks from climate change.

4.5.2 Sensitivity

Sensitivity explains the human and environmental conditions that can either worsen the hazard or trigger an impact (Gbetibouo and Ringler, 2009). From Figure 4.17 and Table 4.7 it is clear that Tuolung, Kaane Dalle and Kul Ora communities are more sensitive to climate change with both recording vulnerability values of 0.60, 0.51 and 0.50 respectively. The higher sensitivity of Tuolong community could be as a result of high sensitivity of the higher LVI recorded for percent of households whose farmland are affected by floods and due to the fact that, floods rendered their ; infertile and farmers usually left the non-fertile lands for some time to fallow before carrying ny agricultural activity. They also indicated that, the floods destroyed their crops especially e which they said did not require much water to grow (drought-tolerant). Also the greater the rrences of floods, the more sensitive farmers are likely to be to flood impacts. This finding ıates with the work of Antwi *et al*. (2012), who noted that flood disasters come with massive cts including severe injuries and property loss.

ıdicated by a farmer:

!011 and 2015, we lost our maize crops and some livestock to floods which affected our food ability. We did not harvest enough maize and rice to feed our families all year-round when the floods occurred. We usually had enough food to feed our families in seasons without floods even up to the next harvest time. But in seasons with floods we experienced a lean season (usually from March to July which is the critical time of the year where they lack sufficient food)".

Plate 4. 2: Flooded Maize farm at Tuolung Community

Source: Field survey, 2018

. though the overall sensitivity of Guo community is not high (LVI 0.48), Indicator wise, it 'ded the highest LVI value interms of Household heads who reported very high farmland on (LVI 0.89). This may be due to the activities of illegal mining also known as “Galamsey” n the community. Illegal mining is gradually degrading agricultural lands within the nunity consequently leading to erosion which reduces the fertility, stability, and therefore the uctivity of soils. This could have a negative effect on food production and a threat to the hood of the community. This has made Guo community more exposed and sensitive to the cts of climate change.

Plate 4. 3: Illegal Mining "Galamsey" activities at Guo Community

Source: Field survey, 2018

ndicators were selected to analysis sensitivity of rural household to climate change. Kul-Ora Tuolung recorded the highest LVI value for households' inability to reserve crops for the time od shortage (0.41 and 0.39 respectively) and the lowest was recorded for Guo community).

ne communities recorded a higher vulnerability index values for households who owned from poor to medium farmland fertility with Kul-Ora recording the highest value of 0.88. Kaane-Dalle and Tuolung recorded LVI values of 0.82 and 0.81 respectively. Lower values for vulnerability index were generally recorded for households' inability to reserve seeds for future cropping season with Kul-Ora recording the lowest of 0.11. Tamparizie recorded the highest value for vulnerability index interms of distance to the nearest fertilizer market. On the average, the distance to the nearest source of fertilizer market recorded was 0.66. In all the communities, the higher sensitivity of livelihoods of the vulnerable households is due to high dependence on climate-sensitive agriculture for income.

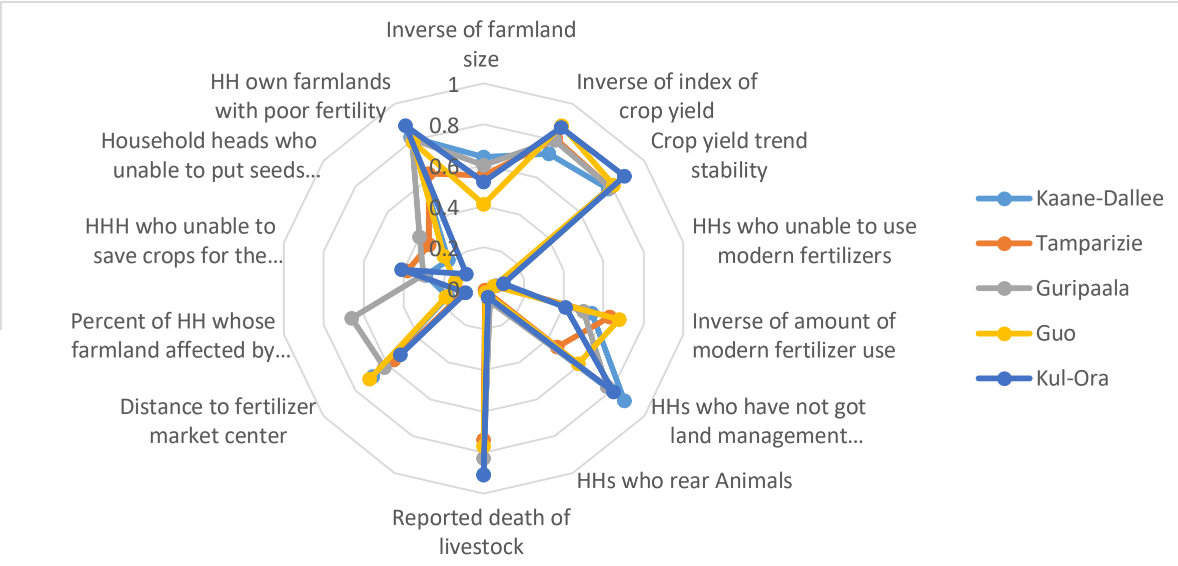


Plate 4. 4: Vulnerability radar diagram of agricultural land indicators

ce: Field Survey, 2018

Adaptive Capacity

e *et al*. (2012) defined adaptation to climate change in agriculture production as the adjustment rming activities or methods in line with changing climatic conditions in order to reduce the ıtial adverse impacts on food production. To them farmers can achieve the objectives of food security, high income and secured livelihood if they are able to adapt effectively to climate change (Mabe *et al*., 2012). Seven indicators were selected to analyze the adaptive capacity of the study communities. From table and fig, Kul-Ora (0.52) and Kaane-Dalle (0.53) communities are more vulnerable interms of Adaptive capacity as compared to the rest of the communities. Tamparizie recorded a lower vulnerability index value of 0.46 followed by Guo (0.49). Indicator wise, Kaane Dalle recorded the highest level of vulnerability in terms of Limited access to land management training (0.88) followed by Kul-Ora which recorded 0.81. Tamparizie community recorded the lowest of 0.35. It is noted by Woodfine (2009) that access to land management training as a climate change adaptation measure is very important as it can generate benefits for farmers, by improving soil fertility and structure, conserving soil and water, enhancing the activity and diversity of soil fauna, and strengthening the mechanisms of elemental cycling. The literature suggests that these benefits can lead to increased productivity and stability of agricultural production systems.

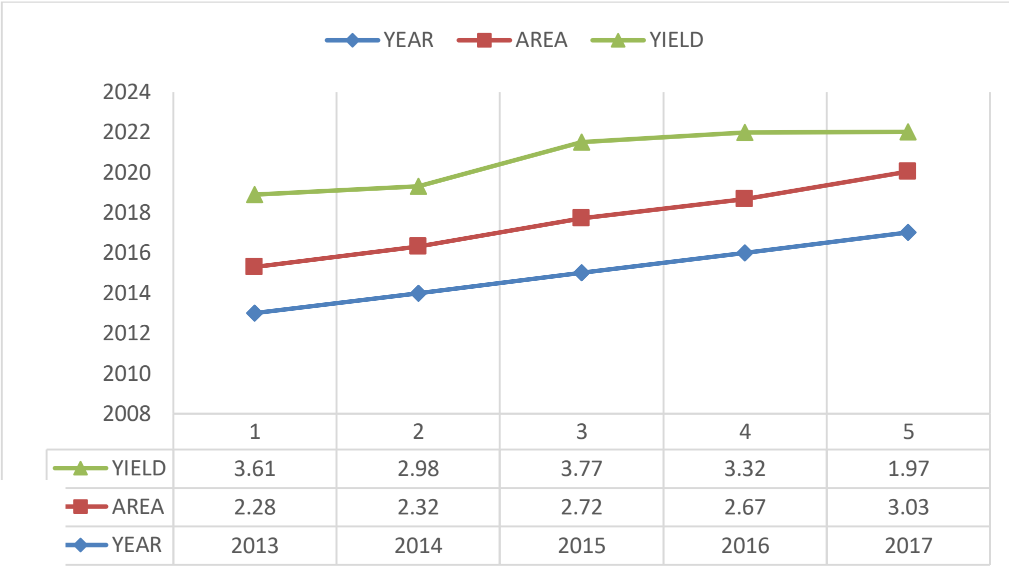
They thus offer a potentially important means of enhancing agricultural returns and food security, as well as reducing the vulnerability of farming systems to climatic risk. Guo recorded the highest ɜrability interms of inverse of amount of modern fertilizer used (0.68) whiles the lowest was ·ded for Kul-Ora (0.41). In general, the vulnerability levels of households were unable to use ɜrn fertilizer was lower for all the communities with only Kul-Ora recording 0.1 whilst the ɔf the communities recorded between 0.050 to 0.065. Mabe *et al*. (2012) identified the use of :hemicals as an important adaptation strategy to climate change. The people said that due to ning rainfall and continuous cultivation of the land, the soil fertility kept reducing, hence the for fertilizer application. "*The soil is no more fertile because of how the rain has changed people use crop varieties that are new. So if you don't apply fertilizer, you will not get ıing"*. These are the words of an old farmer. The size of farmland holding under cultivation in a community is a sub indicator for the possible amount of agricultural production. In the rural communities, it is assumed that the larger the farmland holding allows for more opportunities to have more crops and yield, and hence the lower the vulnerability to climate change impacts though it is noted that labor availability and financial capital both affect the reality of how much land can be cultivated. The results on land size indicators also showed that the total vulnerability level of the households to climate change impact was found to be higher. Kaane-Dallee is more vulnerable interms of inverse of land size owned (0.64) followed by Tuolung which recorded a value of 0.60.

The least vulnerability in terms of inverse of farmland size was Guo community (0.41). Less agricultural area is often attributed to have a negative impact on the rural communities and increased farmers' levels of vulnerability to climatic risks (Barungi and Maonga, 2011).

Table 4. 7: vulnerability indices for the various categories of vulnerability

COMMUNITIES	LVI For Adaptive Capacity Indicators	LVI for Sensitivity Indicators	LVI For Exposure
ni-Dalle	0.53	0.51	0.48
ıparizie	0.46	0.46	0.49
lung	0.51	0.60	0.53
)	0.49	0.48	0.53
-Ora	0.52	0.50	0.45

yield per hectare including its long-term declining trend is an important measure of farmland ty and vulnerability to climatic risks. The results on these indicators indicated that the eyed households are highly vulnerable to climate change impacts by crop yield produced per hectare. The reasons are severe soil erosion resulting from intense rainfall with short duration and poor quality land management practices (see Figure 4.18). Guo community recorded the highest vulnerability interms of inverse of crop yield (0.88) whiles Kul-Ora recorded the highest vulnerability interms of crop yield trend stability (0.88).



re 4. 17: Crop yield trend for the study communities

ce: Field Survey, 2018

ıshi *et al.* (2015) reported a negative relationship between farm size and productivity and .uded that households with large farms find it difficult to adopt an improve methods of farming most strategies come with a cost. The empirical result is also supported by Deininger *et al.* (2013).

e 4. 8: Vulnerability components and indices for each community

Components of Vulnerability	Indicators	Kaane-Dallee	Tamparizie	Tuolung	Guo	Kul-Ora
	STDEV of mean maximum temperature by year	0.4	0.4	0.4	0.4	0.4

EXPOSURE	**STDEV of mean maximum temperature by month**	0.46	0.46	0.46	0.46	0.46
	STDEV of mean minimum temperature by year	0.37	0.37	0.37	0.37	0.37
	STDEV mean of minimum temperature by month	0.5	0.5	0.5	0.5	0.5
	Average Exposure index by Temperature	0.43	0.43	0.43	0.43	0.43
	Average STDEV of RF (1962–2017) by month	0.41	0.41	0.41	0.41	0.41
	Average STDEV of RF (1962–2017) by year	0.52	0.52	0.52	0.52	0.52
	Average exposure by RF	0.47	0.47	0.47	0.47	0.47
	Percent of HH who witnessed droughts	0.89	0.83	0.90	0.89	0.60
	Percent of HH who	0.21	0.27	0.71	0.37	0.25

	witnessed floods					
	Household heads who reported very high farmland erosion	0.58	0.65	0.66	0.82	0.49
LVI		**0.48**	**0.49**	**0.53**	**0.53**	**0.45**
ADAPTIVE CAPACITY	Inverse of farmland size household own	0.64	0.55	0.6	0.41	0.52
	Inverse of index of crop yield	0.73	0.81	0.8	0.88	0.87
	Crop yield trend stability	0.78	0.79	0.79	0.81	0.88
	HHs who unable to use modern fertilizers	0.061	0.065	0.059	0.051	0.1
	Inverse of amount of modern fertilizer use	0.54	0.63	0.5	0.68	0.41
	HHs who have not got land management training	0.88	0.35	0.77	0.59	0.81
	HHs who rear Animals	0.061	0.01	0.071	0.023	0.047
TOTAL LVI		**0.53**	**0.46**	**0.51**	**0.49**	**0.52**

SENSITIVITY	**Reported death of livestock in the past 5 years**	0.906	0.74	0.83	0.77	0.91
	Distance to fertilizer market center	0.69	0.56	0.62	0.71	0.52
	Percent of households whose farmland affected by floods	0.18	0.1	0.66	0.19	0.09
	Household heads who unable to save crops for the time of food deficit	0.29	0.38	0.3	0.14	0.41
	Household heads who unable to put seeds for the next cropping season	0.22	0.34	0.4	0.25	0.11
	Households' own farmlands with poor fertility	0.82	0.62	0.81	0.79	0.88
LVI		**0.51**	**0.46**	**0.60**	**0.48**	**0.49**

Source: Field Survey, 2018

4.6 Total Household Vulnerability Estimated From the IPCC Definition of Vulnerability.

After estimating household vulnerability levels for exposure, sensitivity and adaptive capacity, total household vulnerability was computed. This was arrived at by summing up indices of exposure and sensitivity minus index of adaptive capacity (IPCC). When exposure and sensitivity of households exceeds adaptive capacity, households become vulnerable and vice versa. Households were also put into three categories based on their total vulnerability index which were in both positive and negative values. The categories ranged from highly vulnerable (that is from to 1), vulnerable (from 0.49 to 0) and least vulnerable (from - 0.6 to - 0.1). As shown in table Kul-Ora community was highly vulnerable (0.57), meaning all households fell within 0.5 to nge on the vulnerability scale. The remaining communities Kaane-Dalle, Tamparizie, ɔaala and Guo fell under the vulnerable groups with total vulnerability values of 0.46. 0.33, and 0.49 respectively. None of the communities fell within the least vulnerable range.

e 4. 9: households within total vulnerability index ranges in the five study communities

l vulnerability es	**Kaani-Dalle**	**Tamparizie**	**Tuolung**	**Guo**	**Kul-Ora**
ly vulnerable (0.5 to	-	-	0.62	0.52	-
erable (0 to 0.49)	0.49	0.46	-	-	0.43
Least vulnerable (- 0.5 to - 0.1)	-	-	-	-	-

Source: Field survey, 2018

From the results, Kul-Ora community is highly vulnerable this is because of its low adaptive capacity, a higher sensitivity and higher exposure. High adaptive capacity is required to adjust to the impacts of climate extreme events and if it is limited, vulnerability is likely to increase.

According to Van der Geest (2002), irrespective of the locations, households with limited adaptive capacity suffer higher exposure and higher sensitivity to climate change and extreme events. Households that are poor and have limited access to resources have high vulnerability anywhere regardless of their locations. Adaptive capacity was relatively low in all the communities and was unable to offset their exposure and sensitivity. Higher score in exposure or sensitivity and a lower score in adaptive capacity increases vulnerability.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary, and conclusions drawn from the findings within the parameter of the research objectives and the recommendations of the study. Finally, a summary of recommendations is made on adaptation options with a way forward on the future.

ummary

study was conducted with 180 respondents selected by means of a simple random technique e study areas. Data for the study was collected in five (5) communities across the chosen ct. The analysis involved both qualitative and quantitative approaches. Specifically, the all and temperature trends were analyzed using simple linear regression and standardized pitation index (SPI). Livelihood vulnerability index was used to analyze the levels of rural eholds' agricultural land vulnerability to climate change supported with percentages, ges, maximum and minimum values.

respect to respondents' socio-demographic characteristics, the study established that household's heads who were within the age group of 50 years and above dominated with a percentage of (58.8%). Interms of gender, 89.4% (161) of the household's heads in the study communities were males and 10.6% (19) were females. A large proportion of the sample, represented by 74.4% of the respondents had no formal education. 16.1% of them had primary education, 6.7% of them had secondary/middle school education whiles 2.8% of the household heads had secondary education. 86.7% of the respondents perceived changes in temperature within which 69.5% of respondent's perceived temperature to be increasing. 2.9% observed temperature to be decreasing, whiles 23% observed an erratic pattern in temperature distribution. 88.9% (160) of respondents said yes they have observed changes in the rainfall pattern whiles 11.1% of respondents said no they have not observed changes in rainfall. About 65% (117) of respondents perceived a decrease or reduction in rainfall amount in the community.

The results of the meteorological data showed that annual temperature in the study area had been in increasing trends for the last five decades (1961–2017). The estimated trend line for average annual temperature is y = 0.0224x+27.286. The trend line has a positive slope indicating that the ıge temperature has increased by 1.28 °C in the past 57 years at a significant rate (p=0.01). ɔerature rose by 0.224 °C per decade indicating that there was faster rate of temperature rise e period (1961–2017). The regression line for Maximum Temperature was Y=0.0251x + 38 and Y=0.0197x + 21.733 for that of Minimum temperature. It was found that both of them ɾed increasing trends in the study area. Maximum temperature increased faster while the ːnum temperature increased gradually. For example, the former increased by 1.43 °C at a ficant rate (p=0.0063) while the later increased by 1.12 °C at a non-significant rate (p=0.095) ͽ past 57 years. In decadal time scale, the maximum temperature rose by 0.251 °C and the ːnum increased by 0.197 °C. From the analysis, it is also clear that the mean annual rainfall distribution is gradually declining from time to time. However, long-term rainfall changes in the selected time span, appeared to decrease at a non-significant rate (R2 = 0.066).

Standardized precipitation index (SPI) was used for analyzing the long-term drought pattern in the Jirapa District (refer to Fig.4.7.0). Out of the 57 years, 33 years (57.89 %) recorded below the long-term average annual rainfall amount whiles 23 (40.35%) years recorded above-average. Only the year 1993 received equal rainfall amount with the long-term average rainfall. Most of the positive SPI values occurred between 1962 and 1969 and also between 1995 and 2004. The 1986 rainfall amount was the lowest record in the observation period with SPI value −0.87 whiles the year 1968 recorded the highest amount of precipitation with an spi value of 1.11. The SPI result indicates that long-term drought characteristic in the Upper West Region was found to be 7.89-magnitudes and 0.66-intensity in the 12 years of duration implying high exposure of agricultural land to intense drought conditions in the Jirapa District.

Agricultural land is the main measurement of vulnerability situations of the rural households in this study. In this section, the LVI as developed by Hahn *et al*. (2009) was adopted and modified alyze the livelihood vulnerability levels of rural households to climate change with respect to ıte change impacts on agriculture lands. The findings indicate that; the households' ultural lands are found to be increasingly vulnerable at 0.58 vulnerability index. The erability triangle indicates that Guo community is more exposed to climate change and me events (LVI 0.57) followed by Kul-Ora (0.56) whilst a low exposure status was mined in Tamparizie at 0.48 exposure index value. It was also clear that Kul Ora and Guo nunities are more sensitive to climate change with both recording vulnerability values of 0.67).54 respectively. The high sensitivity of Guo community to climate change may be due to the ities of illegal mining also known as "Galamsey" within the community. Tamparizie and Gurıpaala also recorded the lowest vulnerability interms of sensitivity to climate change (0.32 and 0.3 respectively). Kul-Ora and Guo communities are more vulnerable interms of Adaptive capacity as compared to the rest of the communities. Tamparizie recorded a lower vulnerability index value of 0.47 followed by Kaane-Dallee (0.47).

After estimating household vulnerability levels for exposure, sensitivity and adaptive capacity, total household vulnerability was computed. This was arrived at by summing up indices of exposure and sensitivity minus index of adaptive capacity. The categories ranged from highly vulnerable (that is from 0.50 to 1), vulnerable (from 0.49 to 0) and least vulnerable (from - 0.6 to - 0.1). As shown in table only Kul-Ora community was highly vulnerable (0.57),

The remaining communities Kaane-Dalle, Tamparizie, Guripaala and Guo fell under the vulnerable groups with total vulnerability values of 0.46. 0.33, 0.30 and 0.49 respectively. None of the communities fell within the least vulnerable range.

5.3 Conclusion

study investigated the vulnerability levels of rural household's agriculture lands to climate ge and it has provided enough evidence about the level of farmers' agricultural land erability to climate change risks. Agricultural land is the main measurement of vulnerability tions of the rural households in this study. From the analysis it was revealed that, the various nunities are experiencing increasing exposure and sensitivity to climate change with little tive capacities. Majority of the households are experiencing increasing temperatures and a easing pattern in rainfall. This was confirmed by the 57year meteorological data which was zed.

changing patterns of rainfall, increasing temperatures, droughts and land degradation have ble effects for the poor people who depend upon rain-fed agriculture. The livelihood vulnerability indices (LVI) and total vulnerability have put the households to the most vulnerable position in almost all agricultural land indicators and climatic variables. Most of the results of this study are in line with the findings of several empirical works. All the indicators chosen have impact on the vulnerability of the households in the district.

The scientific observations show that the climate is changing in the study area. Recent evidence includes increasing temperatures, drought frequency and unpredictable rains that fall in shorter but more intense episodes. The magnitude and rate of current climate change, combined with additional environmental, social and political issues, are making many traditional coping strategies ineffective and/or unsustainable, amplifying environmental degradation.

They change in climatic conditions have deepened the vulnerable of agriculture lands among rural households within the district to the impacts of climate change. This has led to a reduction in soil fertility and an increase in soil erosion. The constant exposure of agriculture lands has led to a decline in output and crop yields which will in turn has aggravated the food security status and the of poverty among smallholders whose livelihood is solely dependent on agriculture within listrict. Therefore, measures must be put in place to strengthen the adaptive capacity of eholds to reduce the impact of climate change on their livelihoods

ecommendations

esults from study the indicated that climate change is affecting agricultural lands in the Jirapa ict of Ghana which is making the livelihoods of rural households more vulnerable to its ct. There should be urgent needs for addressing the farmers' problems to enhance community ence through supporting them for the choice of better adaptation strategies. In this regard, the study provides the following recommendations:

- It is suggested that, more education and research interventions should be conducted for enhancing community-based participatory natural resource management approach supported with best indigenous knowledge and practices of farmers.
- It is also suggested that, adaptation interventions should also consider local farmers' resource capacity (low-cost investment in sound agricultural land and soil management techniques).

- The Municipal Assemblies and Meteorological Agencies as well as other Non-Governmental Organizations (NGOs) should inform farming households in the district about impending natural disasters such as floods, droughts, pests among others.
- N.G. O's and Government should step up provision of extension services through the Ministry of Food and Agriculture (MOFA) to enable farmers' to have more access to information about climate change coping and adaptation strategies.
- Also, Government and other intervention organizations should set up community climate change information centres to provide farmers with climate change information as well as access to new climate change coping and adaptation technologies and their usage to enhance their adoption.
- Farmers in the study area should be provided with improved varieties of maize that can withstand drought. This would reduce to probability of losing crops to climate variability and hence render the respondents less vulnerable.

)irection for Future Research

›xpected that the findings of this research will encourage further research interest employing the Livelihood Vulnerability Index to compute the vulnerability status of households to climate change in all the Regions in Ghana.

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APPENDICES

APPENDIX 1: Questionnaire for Household

TOPIC: RURAL HOUSEHOLDS AGRICULTURE LAND VULNERABILITY TO CLIMATE CHANGE IN JIRAPA DISTRICT.

HOUSEHOLD INTERVIEW

Name of Community …………………………… Questionnaire No…………….

e of interview………………………….

RSONAL DATA

1. Name of respondent…………………

2. Age of respondent a. 15 – 29 b. 30 – 49 c. 50 and above

3. Sex a. Male b. Female

4. Educational level

a. None b. Primary c. JSS/Middle d. Secondary

e. Post-Secondary f. Tertiary

5. Household Size a. 5 or less b. 6 - 8 c. 9 -11 d. 12 -14 e. 15 or more

HOUSEHOLD LIVELIHOOD ACTIVITIES

6. What is your main source of livelihood?

a. Farming
b. Trading
c. Public Servant
d. Others (Specify)………………….

7. If farming is your main source of livelihood, do you cultivate crops?

a. Yes

b. No

8. If yes, what are the major crops you cultivate?

(Multiple choice possible)

A. Millet B Maize

C. Sorghum D. Groundnuts

E. Beans F. Rice G. Vegetables

H. Other (Specify…………)

9. What is the quantity of land allocated for each crop selected and their respective yields over the past five (5) years?

CROP	2013		2014		2015	
	Area of land	Crop Yield	Area of land (Ha)	Crop Yield (kgs)	Area of land (Ha)	Crop yield (Kgs)
Maize						
Groundnut						
Rice						
Millet						
Sorgum						
Beans						

CROP	2016		2017	
	Area of land (Ha)	Crop Yield (Kgs)	Area of land (Ha)	Crop Yield (Kgs)
Maize				
Groundnut				
Rice				
Millet				
Sorgum				
Beans				

10. Do you rear livestock?
    a. Yes
    b. No

11. What animals do you keep?

    a. Cattle
    b. Sheep
    c. Goat
    d. Pig
    e. Others (specify)……………………………

ɽCEPTION ON CLIMATE CHANGE

Do you think the weather conditions have changed over the past 10 years?
. No
. Yes
. If yes explain

Do you think temperature has changed over the past 10 years?
. Yes
. No
. If yes explain

If yes, how has it changed over the past 20 years?
. Increased
. Decreased
. Erratic in distribution
d. Do not know

15. Have you witnessed changes in Rainfall amount over the past 10 years?
    a. Yes
    b. Do not know
    c. No change

If yes…….

16. How has it changed over the past 10 years?
    a. Increased
    b. Decreased
    c. Erratic in distribution
    d. Do not know

17. How has the rainfall season in itself changed?

    a. Rains delay,
    b. Rains come earlier than expected
    c. Sometimes come earlier than expected and at other times delay.

EFFECTS OF CLIMATE CHANGE ON AGRICULTURE LANDS

Do you experience soil erosion on your farm lands?

a. Yes
b. No

:s……

What is the rate of soil erosion on your farm lands?

a. Medium
b. High
c. Low
d. Very high

What is the soil fertility level of your farm land?

a. Medium
b. High
c. low
d. very low

21. In the past ten years, what has been the trend of your crop yield?

    a) Improving,
    b) Fluctuating,
    c) No Change,
    d) Declining

22. Have you lost your livestock over the past five (5) years? Yes/No

23. If yes, what do you think are the causes?

    A. Inadequate water
    B. Pests and diseases
    C. Poor pasture
    D. Inadequate labor

E. Others (specify…………………)

24. In the past five years, what has been the trend of your **animal output** and what would you say is the **major** cause for the particular trend?

Output:
a) Improving,
b) Fluctuating,
c) No Change,
d) Declining

Cause:
a. Inadequate water
b. Pests and Diseases
c. Poor pasture
d. Inadequate labor
e. Other (Specify …………………….)

PTIVE CAPACITY OF HOUSEHOLDS TO CLIMATE CHANGE

Type of land ownership:
a. Own land (purchased/Inherited)
b. Rented
c. Shared holding

What is your total farm (crop) size?

A. 1-3 acres
B. 4-6 acres
C. 7-9 acres
D. 10-15 acres

27. Do you apply fertilizers/manure on your crop field?
a. Yes b. No

28. If yes, provide details in the table below

	Yes	No	Type	Quantity Bags/farm

Chemical Fertilizers				
Manure				

29. How long do you travel to reach to the nearest source of fertilizer…………?

Have you been able to reserve some seeds for future cropping season?
a. Yes
b. No

Do you have access to irrigation infrastructure?
a. Yes
b. No

Do you have access to seed and grain storage facilities?
a. Yes
b. No

Have you had access to land management training?
a. Yes
b. No

Have you been made aware of the effects of climate change by the NGO or Local Government?
a. No
b. Yes

35. Have you been informed of the correct weather patterns or changes taking place in the weather (late or early arrival of rains or heavy rains) in time?
   A. Yes
   B. No

If yes, what is the source?

36.
a. Media
b. Extension officers

c. Neighbors
d. Spouse

37. Do you belong to any farmers-based organizations?
    a. Yes
    b. No

38. Have you received any training from the group you belong?
    a. Yes
    b. No

EXPOSURE TO CLIMATE RELATED HAZARDS

Have you experienced droughts over the past five (5) years?
a. Yes
b. No

Have you experienced floods over the past five (5) years?
a. Yes
b. No

Have you been able to save some crops during the time of droughts/floods
Yes
No

Have the kind of pests affecting the crops increased during the last five years?
a. Yes
b. No

Have you found new types of pests on your farm?
a. Yes, No

44. Did you find more weeds growing in the farm?
    a. No
    b. Yes

45. Did you find new types of weeds in the last five years?
    a. Yes
    b. No

46. Are you compelled to increase the quantum of pesticides in the last five years?
    a. Yes
    b. No

APPENDIX 2: Interview Guide for Focus Group Discussion

***TOPIC*: RURAL HOUSEHOLDS AGRICULTURE LAND VULNERABILITY TO CLIMATE CHANGE IN JIRAPA DISTRICT.**

INTERVIEW GUIDE FOR FOCUS GROUP DISCUSSION

1. Do you think there has been a significant change in weather variables over the last 10 years? (Such as temperature, rainfall amount, duration and distribution, sunshine, heat spell etc.)

2. How have the changes been like?

   (i) For temperature

   (ii) For rainfall

   (iii) Other weather variables

3. Have you experienced any climate related hazards over the past ten (10) years?

……………………………………………………………………………….

………………………………………………………………………………

4. Has there being change(s) in the agricultural production output (crop yields/livestock production) for both men and women in the community?

……………………………………………………………………………….

………………………………………………………………………………

5. What accounted for these changes? (i) Extreme weather/climate change events (floods, droughts, heat spell etc.) (ii) Pest/diseases (iii) soil infertility issues

……………………………………………………………………………….

………………………………………………………………………………

6. How do you describe the terrain and nature of your agriculture lands?
……………………………………………………………………………….

………………………………………………………………………………

7. What are the observed impacts of climate change on farmer's agricultural lands?

…………………………………………………………………………….

……………………………………………………………………………

8. Have you been made aware of the effect of climate change by NGOs/local government?

……………………………………………………………………………..

……………………………………………………………………………..

……………………………………………………………………………..

9. Have you been informed of the correct weather patterns or changes taking place in the weather (late or early arrival of rains or heavy rains) in time?

…………………………………………………………………………….

……………………………………………………………………………

10. Have you had access to land management training and who provided the training.

…………………………………………………………………………….

……………………………………………………………………………

11. How long do you walk to access farm inputs (Agro chemicals, Fertilizer, seeds etc)?

…………………………………………………………………………….
……………………………………………………………………………

APPENDIX 3: Questionnaire for institution

INTERVIEW QUESTIONS FOR INSTITUTIONS

A. Institutional Background

Position of interviewee…………………… Date …. /…/…..

Name of Institution……………………………………

of Institution (i) Public (ii) Civic (iii) Private

many years has the organization been operating in the community?....................

Do you perceive climate is changing in the district?

………………………………………………………………….

…………………………………………………………………

If yes, what do you think might be the causes?

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

What are the manifestations of climate change observed in the area?

……………………………………………………………………………..
……………………………………………………………………………..
……………………………………………………………………………..

4. Describe the nature and terrain of agriculture lands in the area

……………………………………………………………………………..
……………………………………………………………………………..
……………………………………………………………………………..

5. What has been the trends of agriculture production within the district? And what might be the causes of this trend?

……………………………………………………………………………..

……………………………………………………………………………..

……………………………………………………………………………..

6. What are the observed impacts on farmers' agricultural lands"?

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

7. How does your institution contribute to support the community address the climate change enges? (e.g education and training; cash aid, food aid and credit; infrastructure improvement; ıology transfer; business advice)

…………………………………………………………………………..

…………………………………………………………………………..

…………………………………………………………………………..

Does every member of the community benefit from these support services?

If no, state target group of beneficiaries

…………………………………………………………………………..

…………………………………………………………………………..

…………………………………………………………………………..

APPENDIX 4: GMA data for monthly rainfall

Station 01013WA- Wa (Met) **Monthly Summary of Observations**

Monthly Rainfall Total (mm)

	Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL	sdev	Mean	annual
	1961	[illegible]	[illegible]	16.0	142.5	152.4	195.8	66.3	91.4	141.0	3.8	8.4	0.0	817.6	73.32	68.1	**817.6**
	1962	[illegible]	[illegible]	132.1	169.9	168.4	136.9	65.8	434.9	182.1	43.4	69.6	0.0	1403.1	121.62	116.9	**1403.1**
	1963	[illegible]	[illegible]	0.0	81.0	110.2	157.5	321.6	278.4	318.0	181.9	6.6	0.0	1542.8	123.59	128.6	**1542.8**
	1964	[illegible]	[illegible]	55.6	32.0	129.3	219.7	218.4	128.2	153.9	29.7	24.6	40.4	1031.8	80.52	86.0	**1031.8**
	1965	[illegible]	[illegible]	33.0	86.4	90.4	161.5	156.7	352.3	250.7	36.6	0.0	0.0	1194.6	111.77	99.6	**1194.6**
	1966	[illegible]	[illegible]	32.5	120.4	130.8	174.2	143.3	176.3	188.2	90.2	0.0	0.0	1057.7	76.84	88.1	**1057.7**
	1967	[illegible]	[illegible]	68.3	74.2	133.9	102.6	115.3	139.9	213.0	53.3	14.2	4.8	919.5	67.06	76.6	**919.5**
	1968	[illegible]	[illegible]	93.0	68.1	124.5	180.9	330.2	263.1	293.4	77.0	7.1	41.7	1533.1	113.07	127.8	**1533.1**
	1969	[illegible]	[illegible]	42.4	47.7	62.7	165.3	257.8	241.5	205.7	159.0	14.5	0.0	1204.7	98.64	100.4	**1204.7**
	1970	[illegible]	[illegible]	0.3	47.7	157.7	69.1	122.7	162.6	152.9	48.0	2.3	0.0	763.3	67.79	63.6	**763.3**
	1971	[illegible]	[illegible]	87.4	27.4	100.1	90.7	180.6	162.1	224.5	43.9	0.0	34.0	959.8	75.27	80.0	**959.8**
	1972	[illegible]	[illegible]	60.2	128.8	121.9	119.6	176.3	173.0	129.5	81.8	0.0	0.0	994.4	68.40	82.9	**994.4**
	1973	[illegible]	[illegible]	14.0	60.5	134.6	134.9	160.0	154.7	139.2	88.4	5.3	30.5	922.1	65.36	76.8	**922.1**
	1974	[illegible]	[illegible]	20.1	39.9	81.3	190.3	272.0	115.1	256.8	69.3	6.1	0.0	1050.9	100.37	87.6	**1050.9**
	1975	[illegible]	[illegible]	31.7	96.8	100.1	96.5	192.0	215.9	227.1	27.7	7.1	0.3	995.2	86.89	82.9	**995.2**
	1976	[illegible]	[illegible]	2.5	74.5	143.8	98.1	105.2	124.3	150.9	288.1	9.4	0.0	999.1	87.94	83.3	**999.1**
	1977	[illegible]	[illegible]	42.7	19.7	189.8	96.1	236.5	250.7	284.5	46.0	0.0	0.0	1225.7	107.56	102.1	**1225.7**
	1978	0.0	0.6	51.2	47.3	76.7	81.6	191.7	112.6	239.5	152.5	1.8	2.5	958.0	80.33	79.8	**958.0**
	1979	0.0	0.0	45.8	96.4	150.8	248.1	247.0	247.6	221.1	45.8	4.8	0.0	1307.4	107.27	109.0	**1307.4**
	1980	18.0	4.5	7.3	142.7	152.3	63.0	134.6	219.6	227.4	162.3	25.9	28.2	1185.8	83.45	98.8	**1185.8**
	1981	0.0	0.0	90.8	29.5	160.2	85.7	109.7	136.0	98.3	45.5	0.0	0.0	755.7	57.84	63.0	**755.7**
	1982	0.0	19.4	26.0	58.8	119.4	116.5	222.2	230.9	162.2	36.7	34.8	0.0	1026.9	83.13	85.6	**1026.9**
	1983	0.0	6.8	20.9	83.7	85.9	89.9	116.3	55.8	139.3	68.7	6.8	0.0	674.1	48.52	56.2	**674.1**

	1984	0.0	0.0	40.6	64.3	129.3	137.9	167.0	152.5	179.7	63.7	1.8	0.0	936.8	71.28	78.1	**936.8**
	1985	0.0	0.0	72.8	77.6	130.5	154.6	186.3	225.0	194.0	0.0	19.0	0.0	1059.8	86.33	88.3	**1059.8**
	1986	0.0	2.3	8.1	33.2	69.2	59.3	107.9	81.5	135.1	24.9	2.2	0.0	523.7	46.50	43.6	**523.7**
	1987	0.0	0.0	18.6	30.3	30.4	104.2	96.6	294.6	104.6	97.5	0.0	0.0	776.8	84.92	64.7	**776.8**
	1988	0.0	0.9	1.1	74.9	114.1	140.1	230.1	104.7	193.2	64.4	7.0	0.0	930.5	80.64	77.5	**930.5**
	1989	0.0	0.0	43.5	41.9	92.9	151.8	114.2	236.7	219.2	105.1	0.0	37.0	1042.3	82.20	86.9	**1042.3**
	1990	[illegible]	[illegible]	0.0	83.2	168.4	87.8	175.3	248.4	106.4	15.9	13.1	7.8	906.3	84.63	75.5	**906.3**
	1991	[illegible]	[illegible]	23.1	115.1	171.4	80.4	237.0	186.1	63.2	130.9	0.0	0.0	1007.6	83.64	84.0	**1007.6**
	1992	[illegible]	[illegible]	0.0	28.2	136.7	205.3	124.7	99.2	180.4	66.7	21.5	0.0	862.7	75.35	71.9	**862.7**
	1993	[illegible]	[illegible]	18.8	152.8	83.9	157.1	183.6	306.5	159.6	64.7	0.7	0.0	1130.2	98.30	94.2	**1130.2**
	1994	[illegible]	[illegible]	17.1	38.9	154.3	176.3	132.1	101.1	245.2	131.0	3.8	0.0	999.8	84.40	83.3	**999.8**
	1995	[illegible]	[illegible]	17.6	101.9	175.6	123.8	188.7	319.6	229.6	68.5	8.6	8.3	1244.1	105.82	103.7	**1244.1**
	1996	[illegible]	[illegible]	26.4	44.2	133.2	94.8	135.8	395.9	196.1	108.2	0.0	0.0	1134.6	115.78	94.6	**1134.6**
	1997	[illegible]	[illegible]	39.2	98.0	188.6	290.6	124.8	128.9	278.1	191.2	18.4	0.0	1357.8	106.15	113.2	**1357.8**
	1998	[illegible]	[illegible]	0.0	66.3	55.1	96.7	117.5	264.8	113.2	42.3	0.0	0.0	767.3	77.68	63.9	**767.3**
	1999	[illegible]	[illegible]	39.2	60.2	92.0	250.2	150.9	193.0	353.3	75.8	1.1	0.0	1290.4	109.89	107.5	**1290.4**
	2000	[illegible]	[illegible]	2.6	76.2	85.1	243.8	149.6	213.8	229.3	73.3	0.0	0.0	1141.2	92.72	95.1	**1141.2**
	2001	[illegible]	[illegible]	tr	85.8	210.9	191.8	84.6	270.0	136.7	26.0	TR	0.0	1005.8	98.25	100.6	**1005.8**
	2002	[illegible]	[illegible]	7.6	95.5	130.0	122.2	240.1	67.4	137.7	41.8	4.7	0.0	847.0	76.37	70.6	**847.0**
	2003	[illegible]	[illegible]	16.7	100.0	181.8	219.5	91.3	220.9	272.6	68.6	16.3	0.0	1199.4	99.17	100.0	**1199.4**
	2004	[illegible]	[illegible]	21.4	84.2	105.1	133.1	177.9	288.7	179.1	43.8	52.9	0.0	1125.8	87.05	93.8	**1125.8**
	2005	[illegible]	[illegible]	18.6	186.0	149.3	135.5	121.3	200.3	215.1	34.7	0.0	0.0	1060.8	87.45	88.4	**1060.8**
	2006	[illegible]	[illegible]	17.4	113.8	95.8	131.8	122.0	226.9	277.7	85.9	1.1	0.0	1072.4	92.85	89.4	**1072.4**
	2007	0.0	0.0	17.4	156.9	198.0	72.4	121.8	186.7	103.3	113.3	26.9	0.0	996.7	74.17	83.1	**996.7**
	2008	0.0	0.0	43.8	80.0	109.3	109.3	220.1	315.3	277.8	117.5	0.0	0.0	1273.1	111.19	106.1	**1273.1**
	2009	0.0	12.8	38.8	74.4	104.1	228.6	162.7	191.0	216.0	111.8	1.5	0.0	1141.7	87.27	95.1	**1141.7**
	2010	0.0	4.0	0	187.5	145.4	48.4	124.3	295.0	156.6	70.7	1.8	0.0	1033.7	96.11	86.1	**1033.7**
	2011	0.0	8.8	17.8	58.2	124.2	131.1	104.2	228.5	208.6	63.1	1.5	0.0	946.0	81.12	78.8	**946.0**
	2012	0.0	7.1	7.3	67.9	139.1	112.0	138.9	138.8	319.9	145.6	2.2	0.0	1078.8	96.16	89.9	**1078.8**
	2013	0.0	64.1	72.6	112.6	95.5	50.0	120.6	251.5	164.5	103.0	10.2	0.0	1044.6	72.81	87.1	**1044.6**

	2014	0.0	0.0	25.8	113.8	79.1	181.5	71.2	130.3	224.3	51.8	36.6	0.0	914.4	73.56	76.2	**914.4**
	2015	0.0	2.0	6.8	24.7	71.2	77.5	80.5	226.5	205.3	117.1	0.0	0.0	811.6	80.05	67.6	**811.6**
	2016	0.0	0.0	49.8	11.6	223.7	44.4	197.8	149.3	148.7	44.5	0.0	0.0	869.8	83.71	72.5	**869.8**
	2017	0.0	0.0	31.7	67.6	121.4	224.7	113.9	108.5	131.4	82.6	0.0	0.0	881.8	70.61	73.5	**881.8**

Table 1: Meteorological Department of the Upper West Region, March 2015

APPEND [illegible] Daily Maximum Temperature

01013WA- Wa (Met) Monthly Summary of Observations														
Mean Daily Maximum Temperature (°C)														
Year	[illegible]	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	Stdev	**Mean**
1961	[illegible]	35.2	36.7	33.8	33.3	29.5	28.7	28.7	29.7	34.5	35.4	34.2	2.85	**32.8**
1962	[illegible]	36.3	36.6	33.8	32.4	29.9	29.6	28.1	29.5	31.9	33.4	34.0	2.76	**32.5**
1963	[illegible]	36.1	35.6	35.2	33.5	31.8	29.8	29.1	30.0	31.0	34.0	34.6	2.53	**33.0**
1964	[illegible]	36.6	36.3	35.7	33.3	30.4	29.1	28.3	29.2	32.6	34.3	32.9	2.89	**32.7**
1965	[illegible]	36.1	37.3	35.2	33.4	30.7	29.6	28.9	29.9	32.8	35.1	34.0	2.73	**33.0**
1966	[illegible]	35.4	36.9	35.6	33.6	30.6	30.3	28.5	29.9	32.3	35.1	34.6	2.75	**33.2**
1967	[illegible]	36.6	36.1	35.4	34.0	31.2	29.1	28.6	29.4	32.8	34.8	33.6	2.78	**33.0**
1968	[illegible]	34.9	35.1	33.7	33.1	30.4	29.4	29.8	29.6	32.8	34.1	34.4	2.19	**32.6**
1969	[illegible]	37.6	37.7	35.5	34.8	31.6	29.5	28.6	29.9	31.4	33.8	35.7	3.14	**33.4**
1970	[illegible]	36.9	38.2	36.6	32.4	32.5	29.9	28.4	29.1	33.8	35.1	34.2	3.20	**33.6**
1971	[illegible]	36.7	36.1	35.5	33.9	30.9	29.0	28.4	29.6	32.9	35.3	33.1	2.88	**33.0**
1972	34.7	36.8	36.7	34.2	32.4	30.8	30.2	29.4	30.7	32.5	34.9	34.6	2.52	**33.2**
1973	35.3	37.9	37.4	37.2	34.3	32.2	30.6	29.3	30.3	33.7	34.5	34.4	2.86	**33.9**
1974	32.9	36.0	36.6	36.2	34.6	32.6	28.6	28.9	29.1	32.6	34.1	33.7	2.83	**33.0**
1975	33.4	36.6	37.1	34.7	32.8	31.5	28.9	29.2	29.4	32.4	34.8	34.4	2.78	**32.9**
1976	33.8	35.8	36.8	35.7	33.0	30.0	29.8	29.4	30.6	30.6	33.0	34.1	2.60	**32.7**
1977	34.7	35.6	36.6	36.1	33.3	31.3	29.7	28.8	30.3	33.3	35.6	34.2	2.67	**33.3**
1978	35.4	37.8	36.2	34.5	33.5	30.9	28.5	30.0	30.6	31.7	33.6	35.1	2.81	**33.2**

1979	35.8	37.0	36.8	36.9	32.7	30.0	29.3	29.6	30.6	32.8	35.1	34.0	2.97	**33.4**
1980	35.6	36.4	37.6	35.7	31.2	32.5	30.0	29.2	30.7	32.4	33.5	32.5	2.69	**33.1**
1981	34.0	37.2	36.5	35.6	33.3	32.0	29.8	29.7	30.7	34.0	35.5	36.0	2.62	**33.7**
1982	34.3	35.6	35.9	33.9	34.3	31.2	30.1	30.0	30.8	32.8	32.9	34.0	2.04	**33.0**
1983	31.8	37.2	38.3	36.8	33.7	31.0	30.0	29.8	30.7	34.5	35.3	35.3	2.98	**33.7**
1984	34.6	36.5	36.9	36.2	34.1	32.3	30.2	29.6	30.3	32.6	35.1	33.3	2.53	**33.5**
1985	[illegible]	34.4	36.8	34.9	33.8	32.3	29.0	29.1	29.5	33.7	35.7	33.1	2.65	**33.1**
1986	[illegible]	37.2	37.7	36.7	34.8	33.3	29.7	29.2	30.1	32.6	34.1	33.3	2.85	**33.6**
1987	[illegible]	37.9	37.6	37.5	35.6	32.1	30.4	29.7	31.1	32.3	35.6	34.4	2.93	**34.2**
1988	[illegible]	37.3	38.6	36.1	35.1	31.1	29.5	29.7	30.3	33.9	35.3	33.3	3.01	**33.7**
1989	[illegible]	35.1	36.3	36.7	35.7	31.6	30.1	29.2	30.3	32.6	36.1	34.4	2.66	**33.5**
1990	[illegible]	36.1	38.4	36.7	34.4	32.1	29.7	30.0	31.0	34.4	35.9	35.1	2.75	**34.0**
1991	[illegible]	38.0	38.4	35.6	31.6	32.0	29.9	29.3	31.6	32.4	35.0	34.2	2.96	**33.6**
1992	[illegible]	37.1	38.3	37.3	33.6	30.7	29.6	29.3	30.7	33.9	33.8	35.7	3.08	**33.6**
1993	[illegible]	37.3	36.8	36.1	34.5	33.0	30.3	30.0	30.6	33.3	35.6	34.9	2.51	**33.8**
1994	[illegible]	37.0	38.2	36.9	34.0	31.6	30.1	29.6	30.8	31.6	34.7	33.9	2.86	**33.6**
1995	[illegible]	36.7	38.1	36.1	34.0	32.4	30.2	29.6	31.2	33.1	35.1	35.0	2.62	**33.8**
1996	[illegible]	37.7	37.4	35.8	24.3	31.6	30.5	29.7	30.0	32.8	34.9	35.7	3.99	**33.1**
1997	[illegible]	35.8	37.3	34.8	34.1	31.0	30.4	30.4	31.1	32.8	34.7	34.9	2.41	**33.6**
1998	[illegible]	37.9	38.9	37.4	34.6	32.7	30.8	29.4	29.8	32.8	35.7	34.9	3.12	**34.1**
1999	[illegible]	35.2	37.7	36.0	35.0	32.2	29.7	29.2	29.8	31.9	35.3	34.6	2.82	**33.5**
2000	[illegible]	34.7	37.8	36.4	33.9	31.5	30.1	30.0	30.1	32.9	35.7	34.4	2.62	**33.5**
2001	[illegible]	37.0	38.9	37.1	34.7	31.9	31.0	29.5	30.4	34.5	36.1	36.8	3.05	**34.5**
2002	34.8	37.5	39.1	36.4	34.5	32.0	31.1	29.6	30.8	32.8	35.5	35.1	2.89	**34.1**
2003	35.8	37.9	38.2	36.3	34.5	30.6	30.2	29.8	30.8	33.4	34.9	35.1	2.98	**34.0**
2004	35.7	36.9	37.0	35.6	33.2	31.6	29.9	29.7	30.8	34.5	35.3	36.2	2.72	**33.9**
2005	34.0	38.0	38.4	36.4	34.4	31.8	30.2	29.8	31.6	33.7	36.1	36.2	2.90	**34.2**
2006	36.5	37.1	38.5	37.5	34.5	32.7	31.3	30.4	30.7	33.2	35.8	35.4	2.77	**34.5**
2007	34.2	37.8	38.6	35.3	33.5	32.5	31.7	29.5	31.4	33.7	34.9	34.9	2.59	**34.0**
2008	33.1	36.9	37.8	36.5	34.8	32.9	30.3	29.5	30.6	32.9	35.7	35.6	2.76	**33.9**

2009	34.6	37.4	36.9	36.2	34.9	32.6	30.4	29.5	30.5	32.6	34.7	36.4	2.72	**33.9**
2010	37.2	38.6	38.8	36.5	34.4	32.5	30.9	30.2	30.3	32.1	35.9	35.7	3.14	**34.4**
2011	34.9	36.8	38.3	37	34.4	32.5	30.9	30	31.0	33.2	36.2	35.1	2.69	**34.2**
2012	35.2	36.7	38.3	36.3	33.6	31.9	30.0	30.1	30.4	32.7	35.9	35.5	2.84	**33.9**
2013	35.5	37.5	37.4	34.5	34.3	33.1	30.6	29.2	30.4	33.1	36.0	35.2	2.71	**33.9**
2014	25.9	37.2	38.1	30	33.7	32.1	31.3	30.7	30.4	33.9	35.1	35.9	3.47	**32.9**
2015	[illegible]	[illegible]	38.4	38.4	37.0	32.7	31.5	29.9	31.1	34	36.2	33.8	3.07	**34.3**
2016	[illegible]	37.7	38.3	35.8	34.1	31.9	30.4	30	31.0	34.4	36.9	36.4	2.88	**34.3**
2017	[illegible]	38	39.5	38	36.0	32.5	31.1	29.4	31.6	35.2	37.2	35.6	3.17	**35.0**

APPEND[illegible]ALUES

Year	**J[illegible]**	[illegible]	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1961	-[illegible]	[illegible]08	-0.518	1.478	0.654	0.999	-1.523	-1.345	-0.874	-1.458	-0.030	-0.375
1962	-[illegible]	[illegible]08	3.645	2.130	1.048	-0.012	-1.531	2.832	-0.217	-0.694	4.437	-0.375
1963	-[illegible]	[illegible]01	-1.092	0.014	-0.385	0.342	2.675	0.929	1.954	1.977	-0.161	-0.375
1964	-[illegible]	[illegible]08	0.902	-1.152	0.086	1.409	0.978	-0.898	-0.668	-0.958	1.152	3.289
1965	1[illegible]	[illegible]35	0.091	0.142	-0.872	0.410	-0.036	1.827	0.879	-0.825	-0.643	-0.375
1966	-[illegible]	[illegible]07	0.073	0.952	0.123	0.628	-0.257	-0.313	-0.120	0.208	-0.643	-0.375
1967	-[illegible]	[illegible]08	1.357	-0.148	0.199	-0.601	-0.717	-0.755	0.277	-0.503	0.393	0.061
1968	-[illegible]	[illegible]24	2.243	-0.293	-0.033	0.743	2.816	0.743	1.561	-0.046	-0.125	3.407
1969	-0.281	0.046	0.428	-0.779	-1.554	0.476	1.626	0.480	0.160	1.535	0.415	-0.375
1970	-0.281	-0.408	-1.082	-0.779	0.785	-1.176	-0.595	-0.479	-0.684	-0.606	-0.475	-0.375
1971	-0.281	0.102	2.042	-1.262	-0.633	-0.805	0.357	-0.485	0.460	-0.685	-0.643	2.709
1972	-0.281	-0.223	1.067	1.152	-0.097	-0.309	0.286	-0.353	-1.058	0.046	-0.643	-0.375
1973	-0.281	-0.408	-0.590	-0.474	0.216	-0.046	0.018	-0.575	-0.903	0.174	-0.256	2.392
1974	-0.281	-0.408	-0.371	-0.964	-1.096	0.905	1.860	-1.057	0.976	-0.195	-0.198	-0.375
1975	-0.281	-0.408	0.045	0.390	-0.633	-0.705	0.544	0.169	0.502	-0.997	-0.125	-0.348

1976	-0.281	-0.279	-1.003	-0.141	0.443	-0.678	-0.883	-0.945	-0.716	4.025	0.043	-0.375
1977	4.202	-0.195	0.439	-1.445	1.575	-0.712	1.276	0.592	1.419	-0.644	-0.643	-0.375
1978	-0.281	-0.374	0.744	-0.788	-1.209	-0.961	0.539	-1.087	0.700	1.410	-0.512	-0.148
1979	-0.281	-0.408	0.550	0.380	0.615	1.897	1.448	0.554	0.406	-0.648	-0.293	-0.375
1980	1.163	-0.155	-0.830	1.482	0.652	-1.281	-0.400	0.214	0.507	1.599	1.247	2.183
1981	-0.281	-0.408	2.164	-1.212	0.846	-0.891	-0.809	-0.803	-1.556	-0.654	-0.643	-0.375
1982	-[illegible]	[illegible]0	-0.160	-0.514	-0.158	-0.362	1.041	0.351	-0.535	-0.823	1.897	-0.375
1983	-[illegible]	[illegible]26	-0.343	0.078	-0.983	-0.819	-0.700	-1.778	-0.901	-0.206	-0.147	-0.375
1984	-[illegible]	[illegible]08	0.364	-0.384	0.086	0.005	0.133	-0.602	-0.256	-0.303	-0.512	-0.375
1985	-[illegible]	[illegible]08	1.519	-0.067	0.115	0.292	0.450	0.280	-0.027	-1.531	0.744	-0.375
1986	-[illegible]	[illegible]79	-0.802	-1.124	-1.394	-1.344	-0.839	-1.465	-0.968	-1.051	-0.482	-0.375
1987	-[illegible]	[illegible]08	-0.425	-1.193	-2.349	-0.573	-1.024	1.126	-1.456	0.349	-0.643	-0.375
1988	-[illegible]	[illegible]57	-1.053	-0.131	-0.289	0.043	1.171	-1.183	-0.040	-0.289	-0.132	-0.375
1989	-[illegible]	[illegible]08	0.468	-0.917	-0.811	0.244	-0.735	0.422	0.376	0.496	-0.643	2.981
1990	-[illegible]	[illegible]08	-1.092	0.066	1.048	-0.855	0.270	0.564	-1.427	-1.225	0.313	0.333
1991	-[illegible]	[illegible]85	-0.264	0.826	1.122	-0.982	1.284	-0.194	-2.117	0.993	-0.643	-0.375
1992	-[illegible]	[illegible]08	-1.092	-1.243	0.268	1.162	-0.562	-1.250	-0.244	-0.245	0.926	-0.375
1993	-[illegible]	[illegible]67	-0.418	1.723	-1.032	0.335	0.406	1.271	-0.577	-0.283	-0.592	-0.375
1994	-[illegible]	[illegible]08	-0.479	-0.988	0.701	0.664	-0.441	-1.227	0.791	0.995	-0.366	-0.375
1995	-[illegible]	[illegible]01	-0.461	0.511	1.226	-0.237	0.490	1.430	0.542	-0.210	-0.015	0.378
1996	-[illegible]	[illegible]08	-0.145	-0.862	0.182	-0.735	-0.380	2.358	0.006	0.556	-0.643	-0.375
1997	-[illegible]	[illegible]08	0.314	0.419	1.546	2.627	-0.561	-0.889	1.317	2.156	0.700	-0.375
1998	-[illegible]	[illegible]1	-1.092	-0.336	-1.741	-0.702	-0.681	0.763	-1.318	-0.715	-0.643	-0.375
1999	0.184	3.453	0.314	-0.481	-0.833	1.933	-0.132	-0.110	2.518	-0.069	-0.563	-0.375
2000	5.132	-0.408	-0.999	-0.100	-1.003	1.823	-0.153	0.143	0.537	-0.118	-0.643	-0.375
2001	-0.281	-0.408	-1.092	0.128	2.095	0.930	-1.222	0.827	-0.943	-1.030	-0.643	-0.375
2002	-0.281	-0.408	-0.820	0.359	0.103	-0.264	1.335	-1.637	-0.927	-0.725	-0.300	-0.375
2003	-0.281	0.248	-0.493	0.466	1.378	1.406	-1.112	0.230	1.229	-0.208	0.547	-0.375
2004	1.852	0.321	-0.325	0.090	-0.510	-0.077	0.312	1.054	-0.265	-0.687	3.218	-0.375
2005	-0.281	-0.408	-0.425	2.513	0.578	-0.036	-0.618	-0.021	0.310	-0.862	-0.643	-0.375

2006	-0.281	-0.408	-0.468	0.795	-0.739	-0.100	-0.607	0.303	1.310	0.125	-0.563	-0.375
2007	-0.281	-0.408	-0.468	1.820	1.777	-1.119	-0.610	-0.186	-1.476	0.654	1.320	-0.375
2008	-0.281	-0.408	0.479	-0.010	-0.407	-0.486	1.006	1.378	1.312	0.735	-0.643	-0.375
2009	-0.281	0.310	0.299	-0.143	-0.535	1.562	0.062	-0.134	0.324	0.625	-0.534	-0.375
2010	-0.281	-0.183	-1.092	2.549	0.482	-1.531	-0.569	1.131	-0.625	-0.168	-0.512	-0.375
2011	-0.281	0.086	-0.454	-0.529	-0.040	-0.112	-0.899	0.322	0.206	-0.314	-0.534	-0.375
2012	[illegible]	[illegible]	-0.830	-0.298	0.327	-0.439	-0.329	-0.769	1.985	1.277	-0.482	-0.375
2013	[illegible]	[illegible]	1.511	0.766	-0.747	-1.504	-0.630	0.602	-0.499	0.455	0.101	-0.375
2014	[illegible]	[illegible]	-0.167	0.795	-1.150	0.754	-1.442	-0.872	0.457	-0.532	2.028	-0.375
2015	[illegible]	[illegible]	-0.848	-1.326	-1.345	-1.032	-1.289	0.298	0.153	0.727	-0.643	-0.375
2016	[illegible]	[illegible]	0.694	-1.638	2.410	-1.600	0.640	-0.641	-0.751	-0.673	-0.643	-0.375
2017	[illegible]	[illegible]	0.045	-0.305	-0.109	1.495	-0.740	-1.137	-1.027	0.062	-0.643	-0.375

APPEND[illegible] Daily Minimum Temperature

Station 01013WA- Wa (Met) Monthly Summary of Observations														
Mean Daily Minimum Temperature (°C)														
Year	**J[illegible]**	[illegible]	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	Sdev	**Mean**
1961	[illegible]	[illegible]	23.1	23.5	23.1	21.7	21.4	21.3	20.9	21.7	20.9	18.6	1.48	**21.3**
1962	[illegible]	[illegible]	23.9	23.7	22.7	21.7	21.9	21.1	21.2	21.8	22.0	18.5	1.80	**21.5**
1963	[illegible]	[illegible]	23.0	23.9	23.7	22.6	22.0	21.7	21.7	21.7	19.6	18.1	1.78	**21.8**
1964	19.5	21.0	24.4	24.4	23.4	21.6	21.6	21.3	20.9	21.3	20.9	20.8	1.51	**21.8**
1965	19.4	21.7	24.1	24.0	23.2	22.1	21.8	21.2	21.2	22.0	20.2	18.1	1.77	**21.6**
1966	18.7	21.1	24.1	24.3	23.8	22.3	22.1	20.6	21.3	21.5	21.2	18.8	1.83	**21.7**
1967	17.9	22.2	24.1	24.3	23.2	22.4	21.2	21.5	21.0	21.5	20.4	19.7	1.82	**21.6**
1968	18.4	22.1	23.2	23.2	23.2	22.2	21.6	21.7	21.2	21.7	21.4	19.9	1.40	**21.7**
1969	19.1	23.4	24.9	25.0	24.1	23.2	21.9	21.6	21.5	21.6	19.8	19.0	2.09	**22.1**

1970	20.2	22.1	25.2	25.2	23.1	22.9	21.9	21.8	21.2	21.9	20.8	19.7	1.73	**22.2**
1971	18.7	22.8	24.3	24.0	23.8	21.9	21.1	21.3	21.1	21.3	20.7	19.8	1.71	**21.7**
1972	19.4	22.8	24.1	24.2	23.4	22.2	21.9	21.7	21.7	21.9	20.2	20.6	1.48	**22.0**
1973	20.3	23.7	24.8	24.9	23.8	22.6	22.6	21.9	21.4	22.4	19.8	19.6	1.81	**22.3**
1974	19.1	21.5	24.4	24.7	23.7	22.4	21.4	21.7	20.9	21.9	19.7	18.0	2.04	**21.6**
1975	18.2	21.6	23.8	24.0	23.0	22.5	21.3	21.2	21.2	21.7	19.9	19.6	1.71	**21.5**
1976	[illegible]	[illegible]	24.0	24.2	23.6	21.8	21.9	21.3	21.4	21.5	20.9	18.1	1.78	**21.7**
1977	[illegible]	[illegible]	24.1	25.5	23.5	22.3	21.6	21.4	21.6	21.5	19.5	18.9	1.85	**21.8**
1978	[illegible]	[illegible]	24.9	24.5	23.7	22.4	21.6	21.9	21.6	21.9	20.8	19.7	1.69	**22.2**
1979	[illegible]	[illegible]	24.9	25.6	23.6	22.5	21.9	22.1	21.9	22.6	22.0	19.2	1.69	**22.4**
1980	[illegible]	[illegible]	24.9	25.2	22.1	23.4	22.3	22.0	22.3	22.3	21.6	18.2	2.12	**22.7**
1981	[illegible]	[illegible]	24.3	25.2	23.9	22.1	22.3	22.1	22.1	23.1	21.2	19.7	1.91	**22.3**
1982	[illegible]	[illegible]	24.3	22.7	24.3	22.9	20.8	22.2	22.1	22.3	20.5	18.8	1.82	**21.8**
1983	[illegible]	[illegible]	25.2	25.8	24.2	22.8	21.5	22.5	21.7	22.9	21.6	19.7	2.34	**22.4**
1984	[illegible]	[illegible]	26.0	25.4	24.3	23.1	21.9	21.2	22.4	22.6	21.7	18.4	2.16	**22.4**
1985	[illegible]	[illegible]	26.3	25.1	24.2	23.2	21.6	21.8	21.4	22.7	21.7	18.4	2.11	**22.6**
1986	[illegible]	[illegible]	25.2	25.7	24.5	23.0	21.9	21.6	21.9	22.3	20.3	18.2	2.38	**22.2**
1987	[illegible]	[illegible]	25.1	26.2	25.2	23.4	22.9	22.3	23.1	22.8	21.3	20.1	1.83	**23.1**
1988	[illegible]	[illegible]	26.7	25.9	25.1	22.8	21.7	22.2	22.0	22.8	21.4	18.9	2.27	**22.7**
1989	[illegible]	[illegible]	24.1	25.1	24.0	22.2	22.0	21.9	21.1	21.8	21.2	19.8	1.92	**21.9**
1990	[illegible]	[illegible]	24.0	25.8	24.1	22.9	22.0	21.6	21.5	22.6	22.8	21.7	1.45	**22.6**
1991	[illegible]	[illegible]	26.1	24.9	23.4	23.8	22.3	21.9	22.1	21.4	20.9	19.3	1.95	**22.6**
1992	[illegible]	[illegible]	25.0	25.1	23.0	21.7	21.1	20.8	20.6	21.6	19.4	18.4	2.14	**21.5**
1993	17.3	21.0	22.1	22.5	22.7	22.4	21.9	21.6	21.9	22.8	23.3	20.3	1.59	**21.7**
1994	20.2	23.1	25.2	25.9	24.1	22.9	22.4	22.4	22.3	22.1	20.7	19.0	1.98	**22.5**
1995	18.9	22.0	25.8	25.3	24.2	23.5	22.6	22.4	22.5	22.9	21.3	21.2	1.87	**22.7**
1996	21.4	24.0	25.7	25.3	24.8	23.0	22.5	21.9	21.9	22.4	20.0	20.2	1.87	**22.8**
1997	21.6	21.5	24.8	24.8	23.9	22.7	22.2	22.5	22.7	23.1	22.2	20.3	1.33	**22.7**
1998	20.3	24.1	25.7	26.8	25.5	23.8	23.4	22.4	22.4	23.1	22.3	20.9	1.93	**23.4**
1999	21.3	22.0	25.6	25.3	24.2	23.2	22.5	22.3	21.7	22.6	22.8	19.4	1.71	**22.7**

2000	22.5	20.7	24.8	25.2	24.1	22.7	22.3	22.2	21.9	22.6	22.6	19.2	1.65	**22.6**
2001	19.9	21.3	25.5	25.6	24.4	22.8	22.9	22.3	22.2	23.6	22.8	21.4	1.69	**22.9**
2002	21.0	22.9	26.9	25.4	24.6	23.4	22.9	22.0	22.3	23.0	22.2	20.1	1.86	**23.1**
2003	21.0	24.6	25.2	25.3	24.4	22.6	22.5	22.5	22.3	23.4	22.8	20.2	1.59	**23.1**
2004	21.3	23.7	24.9	25.0	24.4	22.6	22.0	21.8	21.7	22.8	22.5	22.3	1.28	**22.9**
2005	20.6	25.7	26.5	25.6	24.3	23.0	22.4	21.8	22.2	22.8	22.3	21.4	1.88	**23.2**
2006	[illegible]	[illegible]	26.4	26.5	24.5	23.5	23.0	22.3	22.0	23.2	20.9	19.7	2.04	**23.1**
2007	[illegible]	[illegible]	25.5	25.1	24.5	24.0	23.3	21.7	21.6	22.5	22.9	19.7	1.89	**22.9**
2008	[illegible]	[illegible]	25.2	25.2	25.1	24.0	22.1	22.0	22.5	22.8	21.2	21.1	2.04	**22.7**
2009	[illegible]	[illegible]	25.6	25.4	24.6	22.6	22.1	21.9	22.0	22.5	21.4	20.2	2.01	**22.7**
2010	[illegible]	[illegible]	27	25.9	24.7	23.9	23.1	22.6	22.4	22.8	22.7	20.3	1.97	**23.4**
2011	[illegible]	[illegible]	25.8	26	24.6	23.6	22.4	22.2	22.6	23.3	23.0	19.7	1.86	**23.1**
2012	[illegible]	[illegible]	26	25.6	23.6	23.4	22.3	21.8	21.5	21.9	23.4	21.0	1.76	**22.9**
2013	[illegible]	[illegible]	26.2	24.7	24.2	24.1	22.7	21.8	21.7	22.4	22.5	19.2	1.88	**22.8**
2014	[illegible]	[illegible]	25.2	18.2	24.1	23.4	23.2	22.2	21.6	22.3	21.7	19.4	1.99	**22.1**
2015	[illegible]	[illegible]	25.6	25.7	25.5	24.1	23.2	22.1	22.4	23.1	21.5	18.3	2.28	**19.3**
2016	[illegible]	[illegible]	25.7	26.6	24.5	23.9	22.8	22.5	22.1	22.7	22.4	22.0	1.67	**23.2**
2017	[illegible]	[illegible]	23.7	25.1	25.3	24.1	23.8	22.7	22.7	22.0	20.0	17.5	2.74	**22.0**

Source: M[illegible] Department of the Upper West Region, March 2015

Natural Capital	Unit	Observed value	Minimum Value	Maximum value	LVI
Inverse of farmland size household own	Acre	5	1	9	0.5
owned eroded	%	61	0	100	0.61
d very ınd	%	82.2	0	100	0.822
ndex of	Quintal	3.67	1	17	0.83
nable to for food		29.1	0	100	0.291
HHs who unable to put seeds for the		22.2	0	100	0.22

next cropping season					
Crop yield trend		74.4	0	100	0.74
rear		93.9	0	100	0.061
ave not land ent	%	77.8	0	100	0.78
rket	%	60.08	11	180	0.71
HHs who unable to use modern fertilizers	%	6.1	0	100	0.061

Inverse of amount of modern fertilizer use	No	4.1	0	9	0.54
... mland ... y index					**0.51**
... mean ... e by	^{O}C	2.82	2.04	3.99	0.4
... mean ... e by	^{O}C	1	0.53	1.56	0.46
STDEV of mean minimum	^{O}C	1.9	1.4	2.74	0.37

temperature by year					
STDEV mean of … e by	^{O}C	0.89	0.46	1.32	0.5
…osure … e					**0.43**
…TDEV …–2010)	MM	40.11	11.03	82.24	0.41
…TDEV of RF (1979–2010) by year	MM	86.68	46.5	123.59	0.52

Average exposure to rainfall variability					0.47

8: Calculated Livelihood Vulnerability Index Values

(Source: field survey, 2018)

APPENDIX 9: Regression Analysis for maximum Temperature

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.758852
R Square	0.575856
Adjusted R Square	0.568145
Standard Error	0.36131
ervati	57

OVA

	df	*SS*	*MS*	*F*	*Significance F*
ressio	1	9.748205	9.748205	74.67304	7.96E-12
idual	55	7.179985	0.130545		
al	56	16.92819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
rcept	-16.4299	5.785958	-2.83961	0.006319	-28.0252	-4.83453	-28.0252	-4.83453
X Variable 1	0.025137	0.002909	8.641356	7.96E-12	0.019307	0.030966	0.019307	0.030966

APPENDIX 10: Regression Analysis for minimum temperature

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.468098
R Square	0.219116
Adjusted R Square	0.204918
Standard Error	0.62422
ervati	57

OVA

	df	*SS*	*MS*	*F*	*Significance F*
ressio	1	6.013487	6.013487	15.433	0.000241
idual	55	21.43081	0.389651		
al	56	27.4443			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-16.9625	9.996151	-1.69691	0.095367	-36.9953	3.070185	-36.9953	3.070185
X Variable 1	0.019743	0.005026	3.928486	0.000241	0.009671	0.029814	0.009671	0.029814

APPENDIX 11: Regression Analysis for Average Temperature

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.691617
R Square	0.478334
Adjusted R Square	0.468849
Standard Error	0.392484
Observati	57

OVA

	df	*SS*	*MS*	*F*	*Significance F*
ressio	1	7.768631	7.768631	50.4314	2.57E-09
idual	55	8.472394	0.154044		
al	56	16.24103			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
rcept	-16.6962	6.285163	-2.65645	0.010314	-29.2919	-4.10045	-29.2919	-4.10045
X Variable 1	0.02244	0.00316	7.101507	2.57E-09	0.016107	0.028772	0.016107	0.028772

APPENDIX 12: Degraded land due to floods

Source: filed survey, 2018

APPENDIX 13: Google image Tuolung community, its farmlands and the Black Volta

Table 2 source: Google images, 2018

APPENDIX14: Google image of the “Galamsey” site in Guo Community

ce: Google Maps, 2018

APPENDIX 15: Maize crops cultivated along the Black Volta

ce: Field survey, 2018