UNIVERSITY FOR DEVELOPMENT STUDIES

CLIMATE CHANGE IMPACTS ON SMALLHOLDER AGRICULTURE AND ADAPTATION STRATEGIES IN THE SISILI-KULPAWN BASIN OF THE NORTHERN REGION OF GHANA

BY

MERCY OBENEWAAH OWUSU

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DECLARATION

I, Mercy Obenewaah Owusu, hereby declare that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any University; and that to the best of my knowledge and belief, does not contain any material previously published or written by another person, except where due reference has been made in the text.

Candidate's signature: …………………………………. Date: ……………………………

Name: **MERCY OBENEWAAH OWUSU**

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I, Joseph Amikuzuno, hereby declare that the preparation of this thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

Supervisor's signature: …………………….……….…. Date: …………….………………

Name: **DR. JOSEPH AMIKUZUNO**

ABSTRACT

This study analyzes the impacts of climate change on smallholder agriculture with and without adaptation in the Sisili-Kulpawn Basin (SKB) of the Northern Region (NR) of Ghana. The study used the Cobb-Douglas production function approach to analyze the significant effects of the production inputs used on output levels under the current production systems assuming no climate change. In addition, we estimated the economic outcomes of climate change on farmers' livelihood indicators namely, net returns per farm, net income, and poverty rates using Trade-Off Analysis Minimum Data (TOA-MD) approach. The study took place in the 2013/2014 production season and was based on a sample size of 200 farm households randomly selected from the catchment area of the SKB. The study combined simulated and expected crop and livestock yields under three different climate scenarios and projections made for the year 2030. An intensive and expanded irrigation technology was introduced as climate change adaptation strategy. The findings reveal that smallholder farmers in the SKB were producing in the first stage of the production function having a return to scale value of 0.82 and therefore had the potential to scale-up their input usage per an acre of land in order to reap the maximum gains from the inputs. Also, livelihood outcome variables like income and poverty levels were sensitive to the different climate scenarios, whereby climate change will reduce yields, income, mean net revenue and resilience of farmers in the study area without appropriate adaptation strategies to offset such effects. The use of adaptation to climate change as an entry point is therefore crucial for the improvement of farmers' resilience and disaster preparedness and also for the sustainability of the agriculture sector in the SKB, Northern Ghana and the country as a whole. The study recommends policy focus on improving irrigation access to smallholder farmers including water harvesting and better soil management techniques.

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DEDICATION

I dedicate this piece of work to the Holy Spirit for His strength and guidance; to my dearest Owusu family for their great support and to my husband, Mr. Obed Asiedu for making this research work a successful one.

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AEZ – Agro-ecological Zoning

BNRCC – Building Nigeria's Response to Climate Change

CECAR – Climate and Ecosystem Change Adaptation Research

CFC – Chlorofluorocarbon

CGCM – Canadian Global Coupled Climate Model

CGE – Computable General Equilibrium

CH_4 – Methane

CO_2 – Carbon dioxide

CS – Crop Suitability

CSIR – Council for Scientific and Industrial Research

EEA – European Economic Area

FAO – Food and Agriculture Organization

GDP – Gross Domestic Product

GECAFS – Global Environmental Change and Food Security

GEPA – Ghana Environmental Protection Agency

GHG – Greenhouse Gases

GOG – Government of Ghana

GSS – Ghana Statistical Service

GSSP – Ghana Strategy Support Program

HADCM – Hadley Centre Coupled Climate Model

IFPRI – International Food Policy Research Institute

ILO – International labour Organization

IPCC – Intergovernmental Panel on Climate Change

IWAD - Integrated Water Management & Agricultural Development

KG – Kilogram

MMD – Mamprugo-Moaduri District

MOFA – Ministry of Food and Agriculture

NEST – Nigerian Environmental Study Team

NO_2 – Nitrous Oxide

NPK – Nitrogen Phosphorus Potassium

NR – Northern Region

NRCB - Climate Change and Bioenergy Unit

PEM – Partial Equilibrium Model

SARI – Savannah Accelerated Research Institute

SERI – Sustainable Europe Research Institute

SKB – Sisili-Kulpawn Basin

SPSS – Statistical Package for Social Sciences

SRID – Statistics, Research and Information Directorate

SSA – Sub Saharan Africa

TOA-MD – Trade off Analysis Minimum Data

UDS – University for Development studies

UNFCCC – United Nations Framework Convention on Climate Change

WMO – World Meteorological Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Climate change is the variation in global or regional climates over time, usually over 30 years. Climate change could also be defined as the fluctuations or alterations in the global weather pattern, especially an increase or decrease in temperature and rainfall activities observed for a period of about 30 years (America's Climate Choices, 2010).

Climate change is exacerbating existing vulnerabilities of the poorest people who depend on semi-subsistence agriculture for their survival (Claessens *et al.*, 2011). There have recently been aggravated tensions and concerns among nations and environmentalists over what the impact of climate change will be on the environment and agricultural production (NEST, 2004; BNRCC, 2008; Apata, *et al.*, 2009; Apata *et al.*, 2010). There are also concerns about how resilience of agricultural and food distribution systems will be stressed by unfavorable fluctuations in temperatures and rainfall, especially if such changes are rapid and unplanned (NEST, 2004; Apata *et al.*, 2010). The crucial issue is whether agricultural output supply can keep pace with population increase under climate change and variability (Apata *et al.*, 2010). Hence the greatest challenge of mankind is how to feed an estimated 9 billion people in 2050 by producing about 70% more food under climate change (Bruinsma, 2009; Parry and Hawkesford, 2010; Zhu *et al.*, 2010; Idso, 2011; European Commission, 2011).

Estimates by the Intergovernmental Panel on Climate Change (IPCC, 2007) indicate that agriculture is directly responsible for about 20% of human-generated emissions of greenhouse gases (GHGs). The panel suggested that changes in land use such as deforestation of virgin forests and their conversion into agricultural land alone contributes about 14% of the total human-generated emissions of GHGs. However, land use and land use changes result from changes in global demand for land resources (Ecologic Institute and SERI, 2010). This indicates that, pressure on land is expected to increase as a result of increase in land use and land use changes. This is because of the expected increase in land exploitation in order to feed the world's increasing population which is projected to reach 9 billion by 2050 (Bruinsma, 2009; Parry and Hawkesford, 2010; Zhu *et al.*, 2010; Idso, 2011; European Commission, 2011).

Soil degradation is one of the most serious consequences of land exploitation due to conventional agriculture (Gliessman, 1998). Estimates indicate that 38% of the land cultivated in the world has been damaged to some degree by agricultural practices. Agriculture therefore contributes to climate change through emission of greenhouse gases but is in turn affected by these emissions (FAO, 2008).

In Sub-Saharan Africa (SSA), climate change is projected to intensify the challenges already faced by smallholder farmers. Evidence shows that in arid and semi-arid SSA, vulnerability to climate change is increased by agricultural activities (Roudier *et al.*, 2011) as approximately 80% of the work force is dependent on agriculture as a source of livelihood. Unlike other regions of the world, agriculture in SSA is characterized by very low yields due to poor access to extension services, lack of knowledge and inputs, and low levels of infrastructural investment in irrigation. In addition, high population growth rates, especially in rural areas and intensified pressure on agricultural and natural resources further complicates the challenges of reducing poverty (Calzadilla *et al.*, 2009).

Ghana's economy is predominantly agrarian with about 90% of the population depending primarily on agricultural related activities (Stanturf *et al.*, 2011). However, agriculture in Ghana is largely rain-fed and it is mainly dominated by the rural people who lack the resources to mitigate or adapt to the consequences of climate change. This makes the agricultural sector in Ghana more vulnerable. In Ghana, the erratic nature of rainfall patterns and the uncertainties about climate change will further exacerbate the plight of rural people who rely on the agriculture sector.

The northern region (NR) of Ghana is characterized by destructive land use practices such as over grazing by livestock, cutting down of trees, bush burning and wood charring. This increases the vulnerability of the environment to climate change as evidenced by erratic patterns of rainfall, the threats of desertification, soil erosion and droughts and poor soil fertility.

Considerable number of climate studies have been conducted in Ghana and the reports have shown distinctive inter-annual and inter-decadal variability in major agriculturally-relevant climate variables such as temperature and rainfall (Challinor, *et al.*, 2007; De Pinto *et al.*, 2012; Amikuzuno and Hathie, 2013). In Northern Ghana, this phenomenon may have adverse implications on yields of major staples such as maize, cowpea, millet, sorghum, rice, yam and groundnuts and on livestock production through changes in cropping calendars, cropping systems, incidence of pests and weeds, incidence of drought, food accessibility and consumption (Vermeulen *et al.*, 2010; Amikuzuno and Hathie, 2013). The decline in yields will in turn aggravate the food security situation and the level of poverty among smallholder farmers whose livelihoods are solely dependent on agriculture (Amikuzuno, 2013). Climate change may also create water and heat stress, loss of productive lands through destruction of ecosystems and increased post-harvest losses thereby affecting food supply chains (Vermeulen *et al.*, 2010). Consequently, climate change effects on agriculture may play out through the economic system evidenced by altering prices, output, productivity, demand, calorie availability, and ultimately, human well-being (Amikuzuno and Hathie, 2013).

Vulnerability of Northern Ghana to the changing climate is outstanding as compared to that of the Southern part, due to the terrain and agro-ecology of the region (Stanturf *et al.*, 2011). Flooding from high intensity rainfall and droughts due to the long periods of dry season and a shorter wet season makes Northern Ghana more vulnerable to climate change. Hence in 2007, floods followed by long periods of drought affected about 325,000 people in the Northern savannah zone (Stanturf *et al.*, 2011).

Adaptation involves reducing and responding to the risks that the changing climate poses to people's lives and livelihoods (FAO, 2008). Risk exists when there is uncertainty about future outcomes of ongoing processes or about the occurrence of future events (FAO, 2008). There is therefore the need to reduce uncertainty through improvement activities or adapting to strategy tools such as information base, and devising innovative schemes for resilience against climate change hazards. Adaptive management can particularly be a valuable tool for responding to the unique risks to which different ecosystems and livelihood groups are exposed (FAO, 2008).

IPCC and some recent studies at the sub-continental scale for Africa in this regard have indicated the importance of possible adaptation strategies at the agricultural system and/or household level (claessens *et al.*, 2011). The IPCC Fifth Assessment indicates that, adaptation experience is accumulating across regions in the public and private sector as well as within communities and that, governments at various levels are developing adaptation plans and policies and also integrating climate-change considerations into broader development plans (IPCC, 2014). For instance, in Africa, most national governments are initiating governance systems for adaptation which include disaster risk management, adjustments in technologies and infrastructure, ecosystem-based approaches, basic public health measures, and livelihood diversification to reduce vulnerability (IPCC, 2014).

In Ghana, some coping mechanisms have already been developed as a result of farmers' historical experience with weather variability and extreme events (Stanturf *et al.*, 2011; De Pinto *et al.*, 2012). This includes increased engagement in non-farm activities to generate additional income (Marchetta, 2011). The use of indigenous knowledge to predict weather has become less useful in the wake of climate change. For instance, farmers use the dryness of *Parkia biglobosa* fruits to predict the onset of the rains; the fruits get very dried and ready for harvesting after which farmers get ready for the rain. Also farmers get ready for the harmattan when the weather becomes hot and dry winds blows to the eastern corridor of the SKB. Despite these abilities, smallholder farmers are faced with the challenges posed by the erratic nature of the climate variables. Providing farmers with useful information such as weather and flood forecast couple with best agronomic practices can help reduce the impact of climate change on farmers. With improved adaptive capacity, smallholder farmers will be able to adjust to climate changes.

This study therefore aims at exploring the vulnerabilities of communities along the SKB to climate change. The results are expected to be useful to stakeholders and policy makers for developing intervention or investment to support climate change adaptation.

1.2 Problem Statement

Climate change consequences are projected to be more severe in the next century and this has called for a considerable number of climate impact assessments (Hijmans, 2003; Jones and Thornton, 2003; Thornton *et al.*, 2009a and 2009b; Claessens *et al.*, 2011) across SSA recently. These studies concluded that, crops and livestock yields in SSA will decline if there is no adaptation to future climatic conditions. Also, most previous studies either exclude economic impacts from estimated yield impacts or use statistical methods that required costly multi-year farm-level surveys. These studies neither consider adaptation, cost, or site-specificity in the assessment of impact of climate change (Claessens *et al.*, 2011). These dearth made the use of findings from these studies less uniform across a wide range of conditions. Similarly, data from such studies lack farm level-specific relevance and quantitative economic value.

The three Northern regions of Ghana have already been designated as the poorest regions and the impacts of climate change are expected to be much more severe in these regions. Rainfall-related crop failure has been a common phenomenon in recent times in the regions (Amikuzuno and Donkoh, 2012). This further makes it more necessary to develop models that will more accurately provide data necessary for farmers to strategize their systems of agricultural production in order to minimize the threats posed by the changing climate.

To address the empirical weaknesses of these previous studies, this study seeks to quantify the potential economic impacts of climate change on the gains and losses, gross and net farm revenues, and poverty rates among heterogeneous farm populations in the SKB of the Northern Region of Ghana. The purpose is to assess how climate change, with or without adaptation, will impact the livelihood and how farmers might respond to these impacts through the implementation of adaptation strategies that promote their resilience. This study particularly, seeks to examine how farmers' wellbeing might be affected if future climatic conditions reduce rainfall and increase temperature.

More specifically, this study seeks to find answers to following questions in the SKB;

1. What are the farming systems and adaptation strategies in the SKB?
2. What are the production inputs used and their significant effects on output levels under the current production system in the SKB assuming no change in the climate?
3. What is the trend of rainfall and temperature in selected areas of Northern Ghana for the past 35years (i.e. 1976 to 2011)?
4. What is the economic impact of climate change on livelihoods and how does that relate to yields, income and food security?

It is hypothesized that climate change will reduce the yields and resilience of farmers in the study area and good adaptation strategies will be required to offset such effects.

1.3 Objectives

The objective of this study is to estimate climate change impacts on smallholder agriculture and adaptation strategies in the SKD in the NR of Ghana.

Specifically, the study will:

1. Describe the farming systems and adaptation strategies in the SKB.
2. Analyze the significant effects of production inputs used on output levels under the current production system in the SKB assuming no change in the climate.
3. Describe the trend of rainfall in selected areas of Northern Ghana for the past 35years (i.e. 1976 to 2011).
4. Analyze the economic outcomes of climate change on yields, income and poverty levels, and thus the economic gains and losses to farm households with or without climate change adaptation.
5. Suggest strategies for the development of future socioeconomic scenarios and adaptation strategies for farming systems in the SKB.

1.4 Justification

The semi-arid region of West Africa comprising Northern Ghana, Burkina-Faso, Niger and Mali is a hotspot for extreme climate change-related events like high temperature, floods, droughts and land degradation. In the last decade, the Northern Ghana has already experienced a mix of these events. In 2013, following earlier than expected onset of rainfall, a severe drought gripped much of the Northern Ghana with a high crop failure and its attendant food insecurity.

Extreme weather events related to climate change/variability are expected to continue to rise because of an expected increase in the intensity of anthropogenic activities that cause climate change. The degree of uncertainty associated with climate change/variability projections and impacts is expected to be further widened. This is expected to make it difficult for governments, researchers, and other private-public sector stakeholders to effectively plan for and deal with the causes and effects of climate change in a holistic manner. In this way, the concerns of possible loss of livelihoods, development of adaptation strategies and resilience, and reducing the risk faced by especially smallholder farmers could be difficult to easily address.

To counteract this trend, there is the need to help the multi-stakeholders of climate change appreciate the impacts of climate change in an integrated way. This study intends to provide data that will assist in the enhancement of the capacity of smallholder farmers to adapt to changing climate-related hazards and improving their resilience and disaster preparedness.

This study is motivated by the lack of empirical evidence on especially the economic impacts of climate change on smallholder land use, agricultural production, farmers' income, and poverty and farm-level adaptation strategies. The region is a major hotspot of extreme climate events and thus more vulnerable to the forces of nature, compounded by weak institutions and a high incidence of poverty among its population. This study therefore intends to estimate the economic impact of climate change variables on the actual and potential land use and cropping patterns, as well as outputs and incomes of smallholder farmers in the SKB in the Mamprugo-Moaduri district of the Northern Region.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background

This section presents a review of studies done by other researchers in fields relating to climate change and directly or indirectly relating to the objectives for this study.

2.2 The Climate System

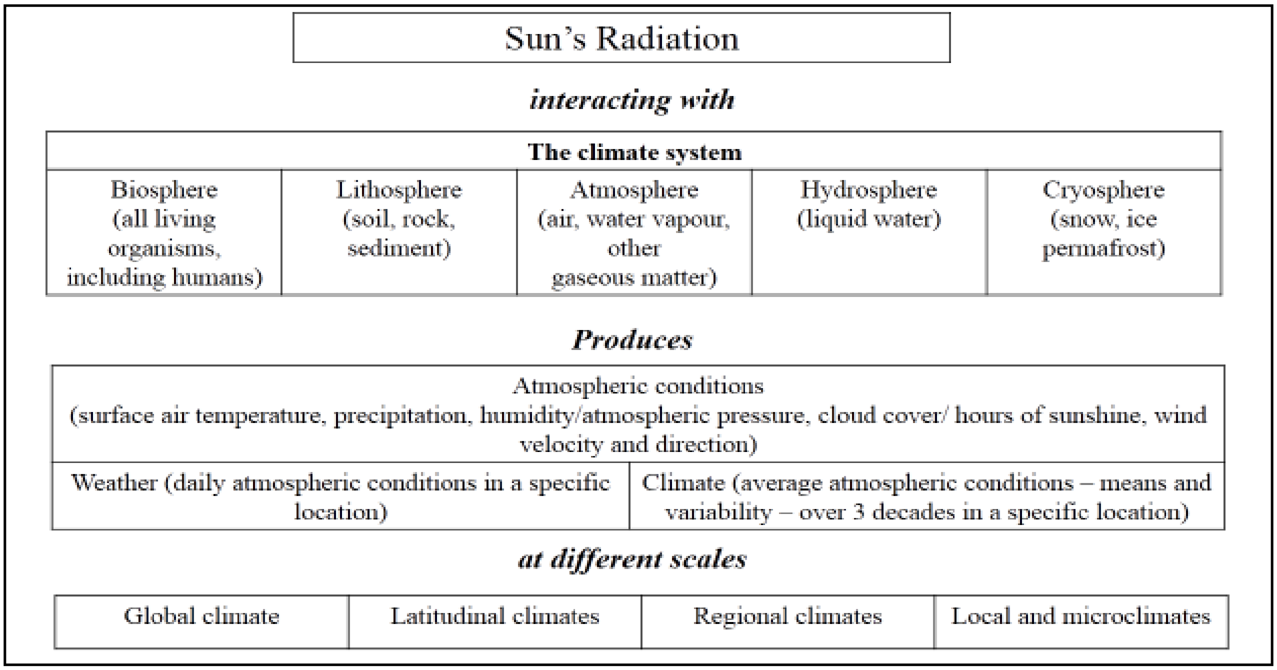
The climate has always been fluctuating through the changes in temperature and rainfall patterns. In establishing how the climate fluctuates, the first thing is to discriminate between weather and climate which are mutually exclusive. "Weather" is the day-to-day state of the atmosphere in terms of temperature, moisture content and air movements; it is derived from the chaotic nature of the atmosphere and is unstable as it is affected by small perturbations (Kropp and Scholze, 2009).

The term “climate”, on the other hand, is a scientific concept. It deals with statistics, such as the averages of all-weather events, over a long period of time (normally, 30 years). Whereas the weather can be directly perceived by people, climate cannot. Or, as a popular phrase puts it: climate is what you expect; weather is what you get (Kropp and Scholze, 2009). So the weather is the state of the atmosphere at any given time whereas climate is what the statistics tell us would occur at any given time of the year. Thus, for example, climate change may involve a single parameter such as temperature or rainfall and weather changes might result in a shift to colder, wetter, cloudier, hotter and windier conditions.

The physics underlying the climate system is well known and widely understood. The earth’s climate is determined by many factors, processes and interactions at a global scale. Important elements include the biosphere, the ocean, sea ice, clouds, and the ways in which these interact. Climate change is linked to the presence of greenhouse gases (GHGs) in the atmosphere (Yamin and Depledge, 2009). The climate system is highly complex and under the influence of the sun’s radiation, the climate system determines the earth’s climate (WMO, 1992; FAO, 2008) and consists of:

- the atmosphere: gaseous matter above the earth’s surface
- the hydrosphere: liquid water on or below the earth’s surface;
- the cryosphere: snow and ice on or below the earth’s surface
- the lithosphere: earth’s land surface (e.g., rock, soil and sediment)
- the biosphere: earth’s plants and animal life, including humans.

Figure 2.1: The formation of climate



Source: FAO/NRCB (2008) in FAO 2008.

The earth's middle and upper atmosphere are strongly influenced by solar variability. Changes in the solar spectral irradiance as well as in the solar wind (a stream of protons that moves radially from the sun) can lead to significant perturbations (Baumgartner *et al.*, 2010). Although climate actually relates only to the varying states of the earth's atmosphere, the other parts of the climate systems also have significant roles in forming the climate, through their interactions with the atmosphere (See figure 2.1).

2.3 Climate Change and Agriculture

Agricultural production serves as a source of food to mankind. Agriculture is important for food security in two ways: it produces the food people eat; and even more importantly, it provides the primary source of livelihood for 36% of the world's total workforce. In the heavily populated countries of Asia and the Pacific, this share ranges from 40% to 50%, and in sub-Saharan Africa, two-thirds of the working population still make their living from agriculture (ILO, 2007; FAO, 2008). Agricultural production has become industrialized and dependent on technology and this has gone a long way to improve productivity, but problems associated with the climate are making it difficult to reach maximum productivity.

Economists have spent almost two decades quantifying the impacts of climate change on agriculture (Seo and Mendelsohn, 2008). FAO (2008) reports that, if agricultural production in the low-income developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be at risk and their vulnerability to food insecurity will increase. Meanwhile, Mariara (2008) indicated that, climate variability is most pronounced in the arid to semi-arid lands that encompass about two-thirds of the African continent.

In Ghana, the agricultural sector comprises approximately 30% of the country's GDP and employs approximately 50% of the population (Kolavalli *et al.*, 2012; De Pinto *et al.*, 2012). The agricultural sector is believed to have the potential to grow at rates as high as 6% (Breisinger, 2008; De Pinto *et al.*, 2012), but climate change could potentially inhibit such progress in the long run the agricultural sector is particularly vulnerable to this ongoing phenomenon – climate change. Ghana is already experiencing an increase in mean annual temperature of 1°C per decade since 1960. Monthly rainfall decreased about 2.4% per decade during the same period, though in the 1960s, the rainfall over Ghana was particularly high (GoG, 2011; De Pinto *et al.*, 2012).

2.4 Climate Change and Food Security

At the global level, food system performance today depends more on climate than it did 200 years ago; the possible impacts of climate change on food security have tended to be viewed with most concern in locations where rain-fed agriculture is still the primary source of food and income (FAO, 2008). Food security is the outcome of food system processes all along the food chain. Food system involves the activities related to production, processing, distribution, preparation and consumption of food (GECAFS Online; FAO, 2008), whereas the food chain is linear, containing a sequence of activities that need to occur for people to obtain food (FAO, 2008). A household's food system comprises all the food chains it participates in to meet its consumption requirements and dietary preferences. However, the climate is particularly an important driver of food system performance at the farm end of the food chain, affecting the quantities and types of food produced and the adequacy of production-related income. Extreme weather events can damage or destroy transport and distribution infrastructure and affect other non-agricultural parts of the food system adversely (FAO, 2008).

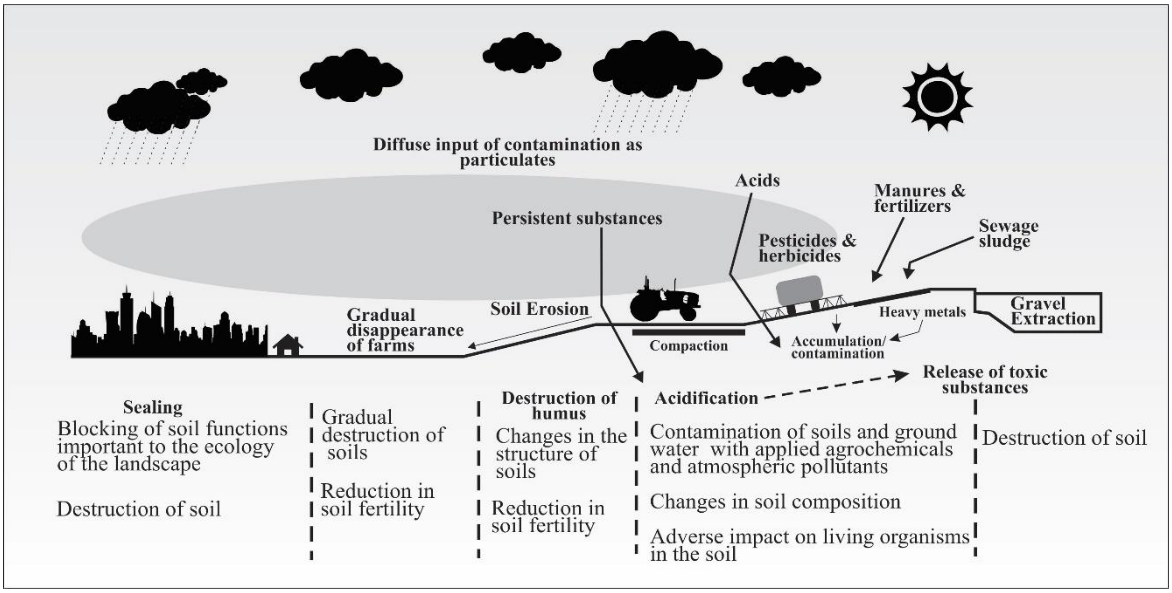
FAO (1996a) indicates that, food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. FAO (2008) reports that, there are four dimensions of food security: food availability, food accessibility, food utilization and food systems stability and that, climate change will affect all these dimensions; as temperature and rainfall vary, agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. This means that, people who are already vulnerable and food insecure are likely to be greatly affected.

Nelson and Agbey (2005) reported that, more than 60% of the Ghanaian population are found in the rural areas and are directly dependent on locally grown crops of food that are harvested from the immediate environment for consumption and for the urban population. The country's agricultural output contributes about 20% to GDP. Major food crops grown in the country include maize, millet, yam, cowpea, cocoyam, plantain and cassava. However, production of these crops is based heavily on climate, and is therefore influenced by weather patterns. It has been observed that during period of drought, crop production and livestock herd declined quite significantly. Nelson and Agbey (2005) also indicated that, in the 1980's particularly in 1983, the severe drought and bush fires encountered nation-wide affected food security in the country leading to starvation in some parts of Ghana. This shows the vulnerability of Ghana's agriculture to prevailing climatic condition and the consequences that a variation in climate would cause to food security if no proper measures are taken.

2.5 Causes of Climate Change

The climate itself is subject to natural variability, and is also influenced by both natural and anthropogenic or human-induced factors (Yamin and Depledge, 2009). The most important challenge is to establish how the scale of these compares with the natural variations of the climate. Natural factors that affect the global climate include variation in the sun's output of energy, ocean currents and volcanic eruptions. There is a wide variety of ways in which human activities can affect the climate through the release of chlorofluorocarbon (CFC) into the atmosphere. These activities include stratospheric ozone depletion (Ozone-hole), greenhouse gas emission, dusts and aerosols and other very small airborne particles from fossil and biomass burning (Yamin and Depledge, 2009). When CFCs come into contact with the sun's ultraviolet rays in the ozone layer, they begin to break down into component atoms, which include chlorine. These disassociated chlorine atoms can then immensely destroy ozone before they diffuse down into the lower atmosphere (Datto and Schiff, 1978; Garfield, 1988).

Figure 2.2: Contribution of Human activities to Climate Change



Adapted from Jones 2002; Ecological Institute and SERI, 2010

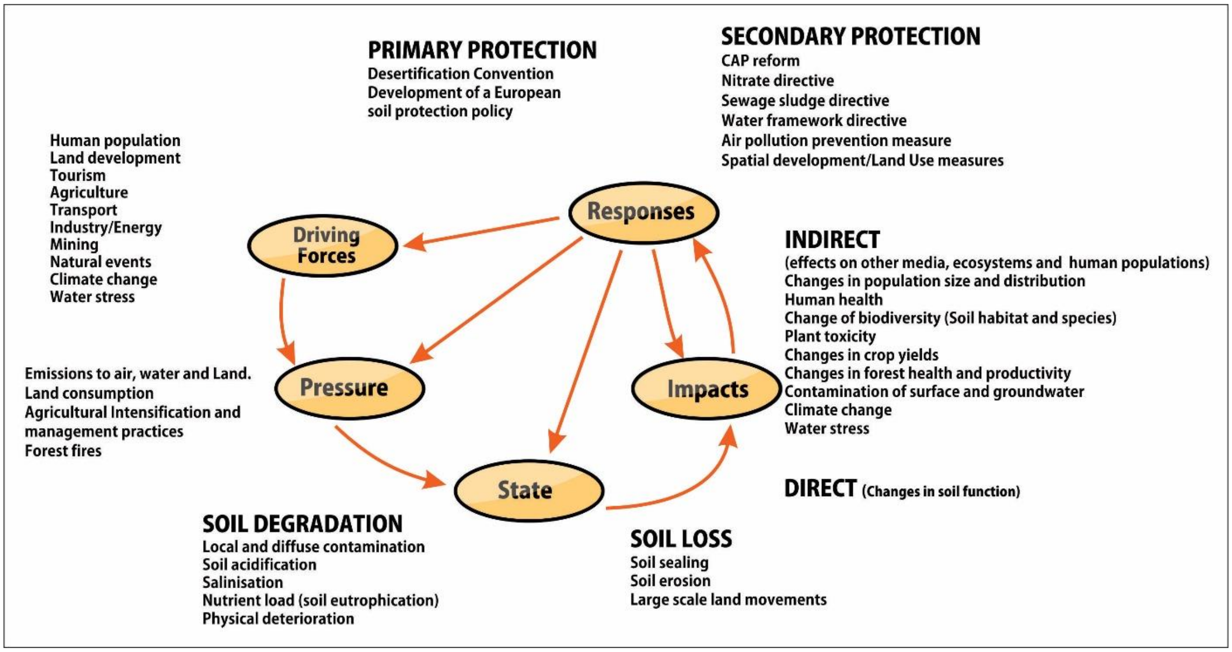
According to the United Nations Conference on Environment and Development (United Nations, 1992), the cutting down of trees is the desiccation of previously moist forest soil, that is, the soil is exposed to the sun, gets baked, and the lack of canopy leaves nothing to prevent the moisture from quickly evaporating into the atmosphere (Selby, 2010). The United Nations (1992) research indicates that the most recent survey on deforestation and greenhouse gas emissions, reports that deforestation may account for as much as 10% of current greenhouse gas emissions. In most sub-humid and semi-arid areas, much of the grazing land is burnt annually during the dry season to remove the old and coarse vegetation and encourage the growth of young and more nutritious grasses (FAO, 2001). Burning causes the loss of soil organic matter and thus impairs the sustainability of agricultural production. Furthermore, it exposes the soil to the erosive forces of the wind during the dry season and of the rain at the end of the dry season. In the drier areas, destruction of trees and other vegetation is an important part of land degradation, widely referred to as desertification (FAO, 2001).

Plate 1: Land clearing by fire and destruction of land by severe drought

Source: FAO, 2001.

Land degradation is induced by human activities. It results from the direct and indirect activities of human. The causes of land degradation have therefore been grouped under the indirect and direct categories (FAO, 2001). The direct causes of land degradation are mainly; deforestation, overgrazing and over-cutting, shifting cultivation, agricultural mismanagement of soil and water resources such as non-adoption of soil and water conservation practices, improper crop rotation, use of marginal land, insufficient and or excessive use of fertilizers. The indirect causes of land degradation are mainly; population increase land shortage, short-term or insecure land tenure, poverty and economic pressure (FAO, 2001).

Figure 2.3: Driving forces of land degradation



Adapted from EEA, 2000; Ecologic Institute and SERI, 2010

Throughout history agriculture has had a significant effect on the world's landscape. Agricultural production has caused greater environmental change to the biosphere than any other land use (Gliessman, 1998). Ecologic Institute and SERI (2010) also reports that, agriculture physically, biologically and chemically affects soils especially through the intensification and industrialization of practices, and through unsustainable management practices including land leveling, excessive irrigation and overgrazing.

Until the industrial revolution of the early 1900's, farming practices were relatively environmentally friendly. Traditional farms were small scale, used biological controls of pests and diseases, used crop rotation to maintain soil nutrients and involved little or no heavy machinery (Gliessman, 1998). The modernization of farming practices in the 1950's resulted in extreme increases in productivity often at the detriment of environmental quality. Modern, or conventional agricultural practices use intensive tillage, irrigation, application of inorganic fertilizers, chemical pest control, and plant genome modification to maximize profit and production (Gliessman, 1998). These practices greatly increased crop yields, and agricultural production rose steadily after World War II. Nonetheless, these practices have numerous long-term ecological impacts such as soil degradation, habitat alteration, water quality impacts, species composition impacts, desertification, deforestation and adverse effects of irrigation.

In Ghana, agriculture is estimated to be the second largest contributor to greenhouse gas (GHG) emissions after the energy sector (De Pinto *et al.*, 2012). Important sources of growth in emissions especially of nitrous oxide (NO_2) and methane (CH_4) are livestock, chemical fertilizers, rice farming, and biomass burning (Brown and Crawford, 2008; De Pinto *et al.*, 2012). Farmers in the Northern part of Ghana engage in activities such as cutting down of trees, bush burning, wood charring, excessive use of chemical fertilizer, high exploitation of farmlands and release of gases into the atmosphere through the use of diesel tractors. Agricultural practices by farmers (such as tillage and crop harvesting) result in soil translocation and this causes disturbance to the soil.

2.6 Consequences of Climate Change

The climate has always been changing. On every time-scale, since the earth was first formed, its surface conditions have fluctuated. Past changes are etched on the landscape which have influenced the evolution of all life forms, and are a subtext of our economic and social history. Current climate changes are the part of the debate about the consequences of human activities on the global environment, while the future course of the climate may well exert powerful constraints on economic development especially in developing countries (Burroughs, 2001).

The changing climate has greater impact on agricultural productivity especially food production. Rough estimates suggest that over the next 50 years, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008; Apata *et al.*, 2010). Specifically, population, income, and economic growth could all affect the severity of climate change impacts in terms of food security, hunger, and nutritional adequacy. If climate change adversely affects agriculture, human effects are likely to be more severe in a poorer world (Apata *et al.*, 2010). Rising demand for food over the next century due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries (Wolfe *et al.*, 2005; Stige, 2006; Orindi *et al.*, 2006; Apata *et al.*, 2010).

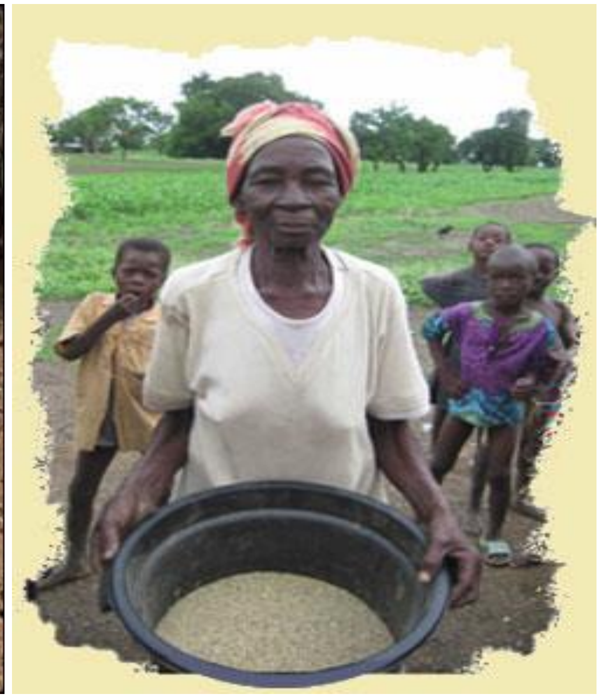
It is projected that crop yield in Africa may fall by 10% to 20% by 2050 or even up to 50% due to climate change (Jones and Thornton, 2002; Enete and Amusa, 2010), particularly because African agriculture is predominantly rain-fed and hence fundamentally dependent on the weather. Enete and Amusa (2010) stated that, the negative effects on agricultural yields will be exacerbated by more frequent weather events. Brussel (2009) had indicated that, rising atmospheric CO_2 concentration, higher temperatures, changes in annual or seasonal precipitation patterns and changes in the frequency of extreme events will affect the volume, quality, quantity, stability of food production and the natural environment in which agriculture takes place (Enete and Amusa, 2010).

Khanal (2009) indicated that, the pattern of climate change has both positive and negative impacts. For instance, rises in temperature helps to grow crops in high altitude areas. However, crops often respond negatively with a steep drop in net growth and yield when temperatures exceed the optimal level for biological processes. Khanal (2009) added that, heat stress as a result of increased temperatures might affect the whole physiological development, maturation and finally reduces the yield of cultivated crop (Enete and Amusa, 2010).

Climate change consequences may also be in the form of drought or floods. Droughts and floods are a particular threat to food stability and could bring about both chronic and short-lived food insecurity. Both drought and floods are expected to become more frequent, more intense and less predictable as consequence of climate change (FAO, 2008).

Plate 2: Climate Change Consequences – Flood Situations

Plate 3: Climate Change Consequences – Drought Situations



Climate change in Ghana might have considerable effect on the country in future (McSweeney *et al.,* 2012). The general trend for temperature change is predicted to increase more in the NR than in the rest of the country. Annual mean temperature is expected to increase by 1°C to 3°C in 2060 and by 1.5°C to 5.2°C in 2090 with changes expected to be more pronounced or severe in the northern parts of Ghana (De Pinto *et al.*, 2012**).** The predicted warming with temperature increases from about 1°C to over 3°C will have adverse effects on human well-being and activities, food security, and water availability (Euronet Consortium, 2012).

Annual mean rainfall is also likely to reduce between 1.1% and 3.1% across all the six agro-ecological zones by 2020, with the highest reduction occurring in the rainforest and the coastal savannah zones. The changes in annual mean rainfall by 2080 is expected to be between 13% and 21% reduction of the observed baseline values (Euronet Consortium, 2012). The overall trend in precipitation over 2006-2050 clearly indicates a downward trajectory in the absence of adaptation to climate change. This will significantly affect agricultural output, and lead to considerable variation in real growth of gross domestic product (GDP). Agricultural GDP is estimated to decline by 3% to 8% compared to the baseline projection for 2050s (Euronet Consortium, 2012).

It is also estimated that 35% of Ghana's land is prone to desertification and that, the desert is increasing by 20,000 hectares a year (Enriquez, 2011). This is as a result of the relatively unrestrained exploitation of some natural resources to meet legitimate socio-economic needs and this extensively damage productive lands and the environment. It is anticipated that climate change in conjunction with these destructive land use practices could accelerate desertification in northern Ghana as rainfall declines and temperatures increase.

With these changes, existing vulnerabilities (to soil erosion, loss of fertility, destruction of biodiversity, recurring drought, deforestation, frequent bush fires, and overgrazing) will be exacerbated (Euronet Consortium, 2012).

Plate 4: Lands approaching desertification in the NR of Ghana

Source: Field Survey, 2013/2014

2.7 Vulnerability to climate change

Vulnerability to climate change result when uncertainty and risk are not managed. Risk exists when there is uncertainty about the future outcomes of ongoing processes or about the occurrence of future events. The more certain an outcome is, the less risk because certainty allows informed choices and preparation to deal with the impacts of hazardous processes or events (FAO, 2008). The vulnerability of people in a given area to the effects of climate change depends on two key factors; the vulnerability of the surrounding natural landscape unit to weather extremes and climatic shifts, and the adaptive capacity of the local population (Nelson and Agbey, 2005).

Global climate change projections have a solid scientific basis, and there is growing certainty that extreme weather events are going to increase in frequency and intensity. This makes it highly likely that asset losses attributable to weather-related disasters will increase. Whether these losses involve productive assets, personal possessions or even loss of life, the livelihoods and food security status of millions of people in disaster-prone areas will be adversely affected (FAO, 2008). Seasonal variations in food supply, along with vulnerabilities to flooding and fire, can make livelihoods more vulnerable at certain times of the year. Although these impacts might appear indirect, they are important because many marginal livelihood groups are close to the poverty margin, and food is a key component of their existence (FAO, 2008).

In Ghana, the vulnerability of the agriculture sector to climate change is largely due to its dependence on rainfall (Yaro, 2010), particularly in the country's semi-arid north. Ghana's agriculture is not only vulnerable to climate change; it also contributes to the problem. The

Northern part of Ghana consists of three administrative regions: Upper East, Upper West and NR. Together, they comprise the poorest region of the country, with poverty rates ranging from 69 to 88% across the region (Shepherd *et al.*, 2005; Nyantakyi-Frimpong, 2013) and thus have a lower intrinsic resilience to any livelihood shock (Euronet Consortium, 2012). In contrast to the more urbanized southern parts of the country, the majority of people in Northern Ghana resides in rural areas and depends on agricultural activities for their livelihoods. Social vulnerability is therefore likely to be severe in these three regions (Euronet Consortium, 2012).

In the Northern Ghana, farming system is predominantly rain-fed for the cultivation of crops such as maize, rice, sorghum, millet, groundnut and vegetables (Dietz *et al.*, 2004; Shepherd *et al.*, 2005; Nyantakyi-Frimpong, 2013). This part of the country is characterized by a unimodal rainfall pattern (starting in April/May and ending in September/October) followed by a dry season that lasts for the remainder of the year. In the last 40years, drought has become a common occurrence and annual rainfall levels are increasingly variable; corresponding to changes in food availability. This has led farmers to develop intricate strategies to adapt.

2.8 Acclimatization, Adaptation and Mitigation strategies

Acclimatization is essentially adaptation that occurs spontaneously through self-directed efforts. Acclimatization is a powerful and effective adaptation strategy. In simple terms, it means getting used to climate change and learning to live comfortably with it (FAO, 2008). Climate change adaptation refers to deliberate adjustments in natural or human systems and behaviours that involve set of actions, strategies, processes, and policies that ***respond*** to actual or expected climatic stimuli (effects) in order to reduce the risks on people's lives and livelihoods (IPCC, 2007; FAO, 2008; Shalizi and Lecocq, 2009; Cap-Net, 2010; De Pinto *et al.*, 2012). Climate change mitigation refers to actions or interventions to ***reduce*** the potentially harmful effects of global warming by reducing GHG emissions or the atmospheric concentration of GHG and also sequester or store carbon in the short term, and development choices that will lead to low emissions in the long term (IPCC, 2007; FAO, 2008; Shalizi and Lecocq, 2009; Cap-Net, 2010; De Pinto *et al.*, 2012).

FAO (2008) suggests some adaptation practices which will help reduce the impact of climate change in the SSA. They include protecting local food supplies, assets and livelihoods against the effects of increasing weather variability and increased frequency and intensity of extreme events, through: general risk management; research and dissemination of crop varieties and breeds adapted to changing climatic conditions and introducing tree crops to provide food, fodder and energy and enhance cash incomes.

Kropp and Scholze (2009) indicate also that local mitigation strategies, such as the installation of solar panels, could also have a tremendous effect on adaptation. For instance, instead of collecting wood for fuel, people have more time for education - a key precondition for adaptation and for livelihood improvement

Several studies conducted in Ghana have suggested adaptation strategies in the country based on the vulnerability of the people identified. Table 2.1 indicates a combined list of potential adaptation strategies and recommendations (from other studies conducted in the country; Armah *et al.*, 2010; Fischer, *et al.*, 2005; Nakuja *et al.*, 2012; De Pinto *et al.*, 2012) for Ghana's agricultural sector.

Table 2.1: Adaptation Option for Ghana's Agricultural Sector

Options	Short-term Options	Mid to Long-term Options
1.Dealing with risk and uncertainty	1. Weather and climate information services and early warning 2. Crop insurance 3. Raising of awareness and access to information 4. Participatory planning or collective action 5. Flood control	1. Climate modeling, impact and vulnerability assessment 2. Strengthening seed systems
2. Farming practices and technologies	1. Indigenous knowledge 2. Drought/flood resistant varieties 3. Crop diversification and specialization 4. Improved crop practices and production technology 5. Pest and disease control 6. Adaptive water management and moisture control 7. Soil conservation and erosion control 8. Fertilization 9. Changing of plot locations 10. Irrigation 11. Extension services and training	
3. Off-farm practices and strategies	1. Improve post-harvest, food storage practices 2. Empower communities and females 3. Improve access to credit	1. Improve access to land or tenure rights 2. Migration 3. Disease prevention
4. National development policy	1. Agricultural intensification and land use policy 2. Access to and governance of water 3. Transportation and other infrastructure 4. Market and price reform 5. Institutional reform 6. Financial incentive for specific practices or inputs 7. Education 8. Reduce inequality or poverty, especially in the North	

Adapted from De Pinto *et al.*, 2012

2.8.1 Strengthening Resilience

Strengthening resilience involves adopting practices that enable vulnerable people to protect existing livelihood systems, diversify their sources of income and change their livelihood strategies. Livelihoods can be defined as the bundle of different types of assets, abilities and activities that enable a person or household to survive (FAO, 2003; FAO, 2008). These assets include physical assets such as infrastructure and household items, financial assets such as stocks of money, natural assets such as natural resources, social assets, which are based on the cohesiveness of people and societies, and human assets, which depend on the status of individuals (this involve education and skill). The amounts of these assets that a household or community possesses or can easily gain access to are key determinants of sustainability and resilience (FAO, 2008). Marginal groups include those with few resources and little access to power, which can constrain people's capacity to adapt to climate changes that could have a negative impact on them.

In Ghana particularly Northern region, the variability of rainfall is a threat to the livelihood of smallholder farmers who are engaged predominantly in rain-fed agriculture. Over the past few years, rainfall-related crop failure has become a common phenomenon due to incidents of late rains for planting, variability in the pattern and levels of rainfall, and intermittent droughts and floods in Northern Ghana. Smallholder farmers have become vulnerable to the climate variability. Thus climate variability involves risks in Ghana, especially in the dryer Northern part of Ghana (Amikuzuno and Donkoh, 2012). There is therefore the need for smallholder farmers to strengthen their resilience through adopting practices that will protect their livelihood systems.

2.9 Approaches to Measuring the Economic Impacts of Climate Change

There are two main types of economic impact assessment models namely the economy-wide (general equilibrium) and partial equilibrium models used to assess the impact of climate change.

Economy-wide models are analytical models that considers the economy as a complete system of interdependent components (industries, factors of production, institutions and the rest of the world) whiles partial equilibrium models are based on the analysis of part of the overall economy such as a single market (single commodity) or subsets of markets or sectors (Sadoulet and De Janvry, 1995; Deressa and Hassan, 2009). Example of economy-wide model used, is Computable general equilibrium (CGE), which is suitable for environmental issues as it is capable of capturing complex economy-wide effects of exogenous changes while at the same time providing insights into micro-level impacts on producers, consumers and institutions (Oladosu *et al.*,1999; Mabugu, 2002; Deressa and Hassan, 2009).

As climate change directly or indirectly affects different sectors of the economy, there is the need to use economy-wide models because CGE incorporates the complex interactions among different sectors and their usage is growing in the areas of climate change impact assessment studies (Winter *et al.*, 1996; Deressa and Hassan, 2009).

Despite the ability of the CGE to assess the complex interactions among different sectors within an economy, it is challenged by the following;

1. CGE has difficulties with model selection, parameter specification and functional forms, data consistency or calibration problems.

2. Due to the absence of statistical tests for the CGE model specification for parameters, the CGE becomes very complex to be used and this therefore requires high skills to develop and use them (Gillig and McCarl, 2002; Deressa and Hassan 2009).

Crop suitability, production function and Ricardian approaches can be classified as examples of the partial equilibrium models (PEM).

2.9.1 The crop suitability (CS) approach

The crop suitability (CS) approach is also referred to as the agro-ecological zoning (AEZ) approach. It is used to assess the suitability of various lands and biophysical attributes for crop production. In the CS approach, crop characteristics, such as technology used, the type of soil and climate factors serves as determinants of CS for crop production (FAO, 1996b; Deressa and Hassan 2009). The CS approach enables the identification and distribution of potential crop-producing lands, and this can be achieved when the variables (crop characteristics) are combined. The climate variable include in the model determines the suitability of agricultural land for crop production, and also used to predict the impact of changing climatic variables on potential agricultural outputs and cropping patterns (Du Toit *et al.*, 2001; Xiao *et al.*, 2002; Deressa and Hassan 2009).

The CS approach has the ability of also addressing adaptation strategies to changing climate conditions. This can be achieved by generating comparative static scenarios with changes in technological parameters within the model (Mendelsohn and Tiwari, 2000; Deressa and Hassan 2009).

Despite the ability of the CS approach, it has a challenge such that the methodology cannot predict possibly, the final outcomes without explicitly modeling all the relevant components. Thus, the omission of one major factor from the model, would substantially affect the model's predictions (Mendelsohn and Tiwari, 2000; Deressa and Hassan 2009).

2.9.2 The production function approach

Production function approach has been used as an important tool of economic analysis in the neoclassical tradition. It is generally believed that Philip Wicksteed (1894) was the first economist to algebraically formulate the relationship between output and inputs as although there are some evidences suggesting that Johann von Thünen first formulated it in the 1840's (Humphrey, 1997; Mishra, 2007).

The production function is defined as a relationship between the maximal technically feasible output and the inputs needed to produce that output (Shephard, 1970; Mishra, 2007). The formulation of production function is based on the assumption that, the engineering and managerial problems of technical efficiency have already been addressed and solved, so that analysis can focus on the problems of allocative efficiency. However, most theoretical and empirical studies defines production function as a technical relationship between output and inputs, with the assumption that output is maximal (and inputs minimal) and often tacit. Moreover, though the relationship between output and inputs is fundamentally physical, production function often uses their monetary values (Mishra, 2007).

The production function has the following advantages;

1. The production function uses several types of inputs that cannot be aggregated in physical units.

2. It also produces several types of output (joint production) measured in different physical units.

3. The production function approach is based on an empirical or experimental production function and it measures the relationship between agricultural production and climate change ((Mendelsohn *et al.*, 1994; Deressa and Hassan 2009). In this regard, the production function could be used to estimate yield changes induced by changes in environmental variables such as temperature, rainfall and carbon dioxide (Adams, 1989; Kaiser *et al.*, 1993; Lal *et al.*, 1999; Alexandrov and Hoogenboom, 2000; Olsen *et al.*, 2000; Southworth *et al.*, 2000; Deressa and Hassan, 2009). The estimated changes in yield could be aggregated to reflect the overall national impact (Olsen *et al.*, 2000; Deressa and Hassan 2009) or incorporated into an economic model to simulate the welfare impacts of yield changes under various climate change scenarios (Adams, 1989; Kumar and Parikh, 1998; Chang, 2002; Deressa and Hassan 2009). This helps to predict the impact of climate change on crop yields through controlled experiments (Mendelsohn *et al.*, 1994; Deressa and Hassan 2009).

Despite the ability of the production function approach, it is challenged in these ways;

The production function estimates do not have the capability to control for adaptation (Mendelsohn *et al.*, 1994; Deressa and Hassan 2009). Meanwhile, in order to properly apply the production function approach, farmers' adaptations should be included in the model (Dinar *et al.*, 1998; Deressa and Hassan 2009). Simulations should also be run with a variety of farm methods such as varying planting dates and crop varieties, dates of harvesting and tilling and irrigation methods. This makes it possible to identify the activities that maximize profit under changing climatic conditions.

In addition to the above challenge, each crop considered under the production function model in general requires extensive experimentation (involving high costs). The use of this methodology has therefore been restricted to the most important crops and a few test locations and hence has limited value for generalizing the results (Kaiser *et al.*, 1993; Deressa and Hassan 2009).

The study proposes to adapt this method (Cobb-Douglas production function) to estimate the significant effects of production inputs used on output levels under the current production system with no climate change scenario.

2.9.3 The Ricardian approach

Deressa and Hassan (2009) used the Ricardian approach that incorporate farmer adaptations to varying environmental factors to analyze the impact of climate change on crop farming in Ethiopia. After collecting data from farm households in different agro-ecological zones of Ethiopia, net crop revenue per hectare was regressed on climate, household and soil variables. The results showed significant impact of the variables on the net crop revenue per hectare of farmers under Ethiopian conditions. The Ricardian approach analyzes a cross section of farms under different climatic conditions and examines the relationship between the value of land or net revenue and agro-climatic factors (Mendelsohn *et al.*, 1994; Sanghi *et al.*, 1998; Kumar and Parikh, 1998; Polsky and Esterling, 2001; Deressa and Hassan 2009).

The Ricardian approach has the following advantages (Deressa and Hassan 2009);

1. It has the ability to incorporate private adaptations. Farmers adapt to climate change to maximize profit by changing the crop mix, planting and harvesting dates, and following a

host of agronomic practices. The farmers' response involves costs, causing economic damages that are reflected in net revenue. Thus, to fully account for the cost or benefit of adaptation, the relevant dependent variable should be net revenue or land value (capitalized net revenues), and not yield.

2. The Ricardian approach takes adaptation into account by measuring economic damages as reductions in net revenue or land value induced by climatic factors.
3. The other advantage of the model is that it is cost effective, since secondary data on cross-sectional sites can be relatively easy to collect on climatic, production and socio-economic factors.

Despite the ability of the production function approach, it is challenged in the following ways;

1. It is not based on controlled experiments across farms
2. It does not also include price effects and carbon fertilization effects (Cline, 1996; Deressa and Hassan 2009).

In reviewing literature on the above-mentioned models, the drawbacks realized were that, the CS methodology cannot predict possibly, the final outcomes without explicitly modeling all the relevant components. The production function estimates too do not have the capability to control for adaptation whereas the Ricardian model does not depend on controlled experiments across farms.

2.9.4 The TOA-MD approach

This approach was first proposed by Antle and Valdivia (2006). The TOA-MD approach has a framework which integrates the physical and economic models at a disaggregate level necessary to capture the heterogeneity of the physical environment and the economic behavior of farmers. Since then, a number of researchers have utilized site-specific data and models to implement analysis of agriculture-environment interactions and related policies that are consistent with the conceptual framework (Antle and Valdivia, 2006). However, high-resolution biophysical and economic data with the geographic coverage needed for analysis of agriculture-environment interactions are exceptional, and provide limited economic information.

In most cases, site-specific economic data are only available from special-purpose farm surveys, and the time and resources required to undertake special-purpose surveys precludes their use for most policy analysis. There is a growing demand for assessment of economic, environmental and social impacts of agricultural technologies (Antle and Valdivia, 2006). One of the great challenges in impact assessment is to "move assessment along the impact pathway" to quantify distributional, environmental impacts, and social impacts of agricultural technologies being developed and disseminated.

However, TOA-MD model demonstrates the possibility to use available data to move a conventional economic impact assessment "along the impact assessment pathway" in order to estimate adoption rates in the relevant populations, and to quantify impacts on distributional outcomes such as poverty, environmental impacts such as soil and water quality, and social and health-related outcomes such as nutrition or gender impacts. The TOA-MD Model is designed to produce information that is timely and sufficiently accurate to support informed decision making for stakeholders and policy decision makers. The TOA-MD model is a unique simulation tool for multi-dimensional impact assessment that uses a statistical description of a heterogeneous farm population to simulate the adoption and impacts of a new technology or a change in environmental conditions.

The TOA-MD approach has the following advantages ((Claessens *et al.*, 2011) ;

1. It has the capabilities of giving projections on climate change.
2. It also has the ability of giving simulations on the climate change effects on crop productivity.
3. The application of the TOA-MD model is relatively simple and reliable.
4. The TOA-MD model evaluates adaptation strategies at the household and agricultural system levels.
5. The TOA-MD model also provides timely assessments of the potential impacts in the context of climate change.

Climate change consequences are expected to be more severe in the next century and have raised many concerns. This has attracted considerable number of climate impact assessments across SSA e.g. Hijmans, 2003; Claessens *et al.*, 2011. The general conclusion from these studies is that, SSA's crop and livestock yields will decline if there is no adaptation to future climatic conditions. Also, most previous studies exclude economic impacts from estimated yield impacts, and neither considers adaptation (Claessens *et al.*, 2011).

This study proposes to adapt the Cobb-Douglas Production function and the TOA-MD approaches for the analysis of the data. The Cobb-Douglas Production function approach will analyze the significant effects of production inputs used on output levels under the current production system without considering adaptation whereas the TOA-MD approach will analyze the economic outcomes of climate change on yields, income and poverty levels, and thus the economic gains and losses to farm households with or without climate change adaptation.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Background

This chapter presents the study area, types and sources of data, data collection procedures, the sampling technique and sample size and the methodologies used for analysis.

3.2 The study Area

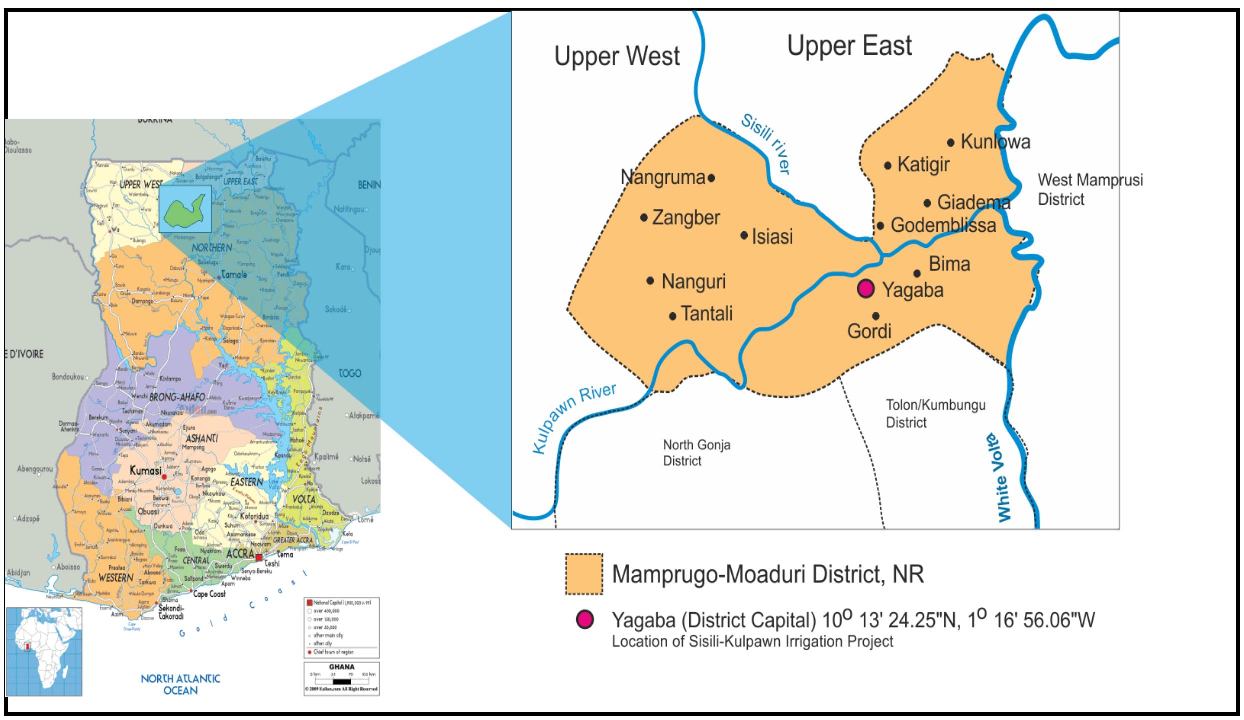
The study is undertaken in the catchment area of the SKB in the Mamprugo-Moaduri District (MMD). The MMD with its capital as Yagaba was carved out from West Mamprusi District and inaugurated on 28th June, 2012.

The district is located within longitudes 0°35'W and 1°45'W and Latitude 9°55'N and 10°35'N. It is bounded by Builsa South district in Upper East region and Sisala East district in Upper West region, West Mamprusi district to the west, North Gonja district and Kumbungu district both to the south; in the NR. The district geology is made up of Middle Voltain rocks normally suitable for rural water supply. The district is largely covered by flat and undulating terrain. The major drainage feature of the district is the White Volta River and its main tributaries such as Sisili and the Kulpawn rivers. Along the valleys of these rivers are large arable land that is suitable for the cultivation of rice and other cereals (Mamprugu-Moaduri District Assembly, 2013).

The district has average temperature ranging from 30°C to 40°C per annum which is distributed from November to April and average rainfall ranging from 1,000mm to 1,200mm per annum, which is also distributed from May to October with August and September as the months with highest rainfall. In November and December, the monsoon trade winds during Harmattan come from the North, and result in cooler nights and days with lower humidity. The area has an abundant arable land (average no. of ha/capita or household) and sunshine to allow the cultivation of a wide variety of crops given sufficient water availability (Wit and Norfolk, 2014).

Figure 3.1 is a map showing the catchment area of Sisili-Kulpawn Basin in the NR.

Fig. 3.1: A map showing the Catchment area of Sisili-Kulpawn Basin in the NR



Source: *ezilon.com, 2009.*

3.2.1 Climate

The district lies within the savannah agro-ecological zone with single maximal rainfall regime, averaging between 1000mm and 1400mm. The rainfall season occurs between May and October, with July to September being normally the peak period in terms of incidence and level of rainfall. Floods occur during the peak period, after which there is a prolonged dry season from November to April. Temperatures are generally high all year round with the hottest month being March. Whiles in the rainy season there is high level of humidity, sunshine with heavy thunder storms, the dry season is characterized by dry Harmattan winds from November-February and high sunshine from March-May.

3.2.2 Agriculture

Subsistence agriculture is the dominant economic activity in the SKB. Along the river valleys are large stretches of arable land, good for cultivation of rice and cereals on a commercial scale. This also presents opportunities to do dry season farming. A wide range of rain-fed crops such as millet, cowpea, maize, rice, sorghum, groundnuts and vegetables can be cultivated throughout the district. The agricultural strategies adopted by local villages are largely in response to the short wet and extended dry season. In fact, these sharp seasonal factors largely drive the subsistence livelihoods adopted by local villages. Rain-fed cropping is undertaken at elevated areas where flood risks are negligible, but where water functions as a major constraint, particularly during the dry season (Wit and Norfolk, 2014).

3.3 Types and Sources of Data

3.3.1 Types of Data

Both qualitative and quantitative data were collected for this research work. The qualitative data collected included crop types, educational level, age, sex and occupation (on-farm and off-farm). The quantitative data collected included farm household size, total land size used for cultivation by smallholder farmers, output of maize, rice, cowpea and millet, productivity and revenue of smallholder farmers. Annual rainfall (mm) and average annual temperature (ºC) from 1976 to 2011 were also collected for some selected areas in the Northern part of Ghana and was used to establish the trends of rainfall and temperature for these areas.

3.3.2 Sources of Data

The Primary data (farm household size, crop types, education, age, sex, occupation, total land size under cultivation, production and output of small farm households) was obtained from 200 smallholder farm households in the SKB through the use of questionnaire with the aid of interpreters where necessary, while the secondary data (production figures for crops, annual rainfall and annual temperature figures) was respectively obtained from the Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture (MoFA) in the NR and from the Department of Climate and Ecosystems Change Adaptation Research (CECAR-Ghana). Table 3.1 shows the production of selected food crops like maize, cowpea, rice, millet and groundnut in the West Mamprusi (Walewale) District.

Table 3.1: Production of Selected Food Crops (Mt)

Year	Maize	Cowpea	Rice	Millet	Groundnut
1991	9,028	9,770	2,679	10,400	12,000
1992	9,028	9,770	9,770	9,770	9,770
1993	6,750	8,600	2,200	8,730	8,810
1994	7,830	10,560	2,420	9,500	11,000
1995	9,020	9,770	2,700	10,440	12,000
1996	7,560	9,343	2,235	10,450	5,434
1997	5,400	8,300	700	8,000	5,600
1998	5,600	7,800	1,600	8,400	6,300
1999	480	9,000	2,002	11,400	6,240
2000	5,600	8,500	9,000	9,000	4,000
2001	4,620	3,920	3,900	2,700	2,100
2002	3,900	7,086	3,000	3,800	3,445
2003	6,480	7,380	5,250	4,680	2,302
2004	6,480	3,900	3,900	3,900	3,900
2005	13,104	3,934	14,482	18,531	22,994
2006	13,184	4,480	14,778	18,180	25,650
2007	8,505	1,800	10,602	13,200	11,952
2008	11,970	3,206	12,500	23,525	15,352
2009	12,110	5,162	11,760	28,500	22,107
2010	13,528	6,750	16,485	13,738	19,560

Source: SRID (2011)

3.4 Sampling size and Sampling technique

3.4.1 Sampling size

A sample size of two hundred (200) small farm households was taken from five communities in the SKB; namely, Kampringbini, Yagakura, Tungbini, Gbingbengu and Zongo with 40 small farm households selected from each of the communities.

3.4.2 Sampling technique

Purposive Sampling technique was used to select smallholder farmers who were predominantly crop farmers from the SKB. The simple random sampling technique was then employed to select 200 smallholder farm households (40 each) from the five (5) different communities mentioned above, within the SKB. A detailed sampling distribution is indicated (See table 3.2).

Table 3.2: Sampling Distribution

Operational zones	Frequency	Percentage
Gbingbengu	40	20
Kampringbini,	40	20
Tungbini,	40	20
Yagakura,	40	20
Zongo	40	20
Total	**200**	**100**

Sources: Field survey, 2013/2014

The interviews with the smallholder farm households took place during the 2013/2014 production seasons.

3.5 Methods of Data Analysis

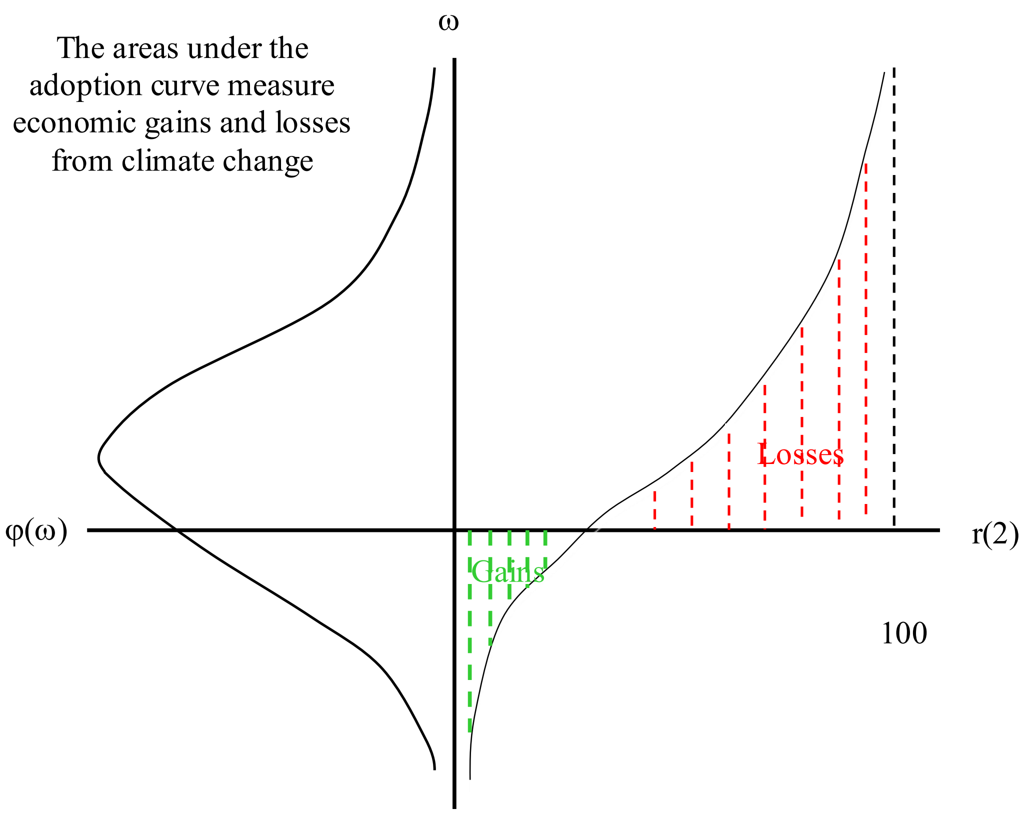
Data was processed using Microsoft Access, Excel and the Statistical Package for Social Sciences (SPSS) software. Data was analyzed economically using the TOA-MD and Cobb-Douglas production function approaches. The TOA-MD approach was used for simulation analysis and the Cobb-Douglas production function approach was used for econometric regression analysis. The regression analysis was used to analyze the significant effects of the production inputs on output levels. Trend of temperature and rainfall was established for some selected areas of Northern Ghana for the past 35years (i.e. 1976 to 2011). The results are presented in tables and charts. Demographic data (farm household size, educational level, age, sex and occupation) was analyzed and presented in tables and graphs as frequencies and percentages.

3.5.1 The TOA-MD model

The TOA-MD model (Antle and Valdivia, 2011) simulates many possible "experiments" for climates impact assessment. It also identifies the production systems and estimates the adoption rate for these systems. The TOA-MD model was therefore employed in the analysis of the different farming systems and adaptation strategies in the SKB and the economic outcomes of climate change on yields, income and poverty levels.

3.5.1.1 The Theoretical Framework

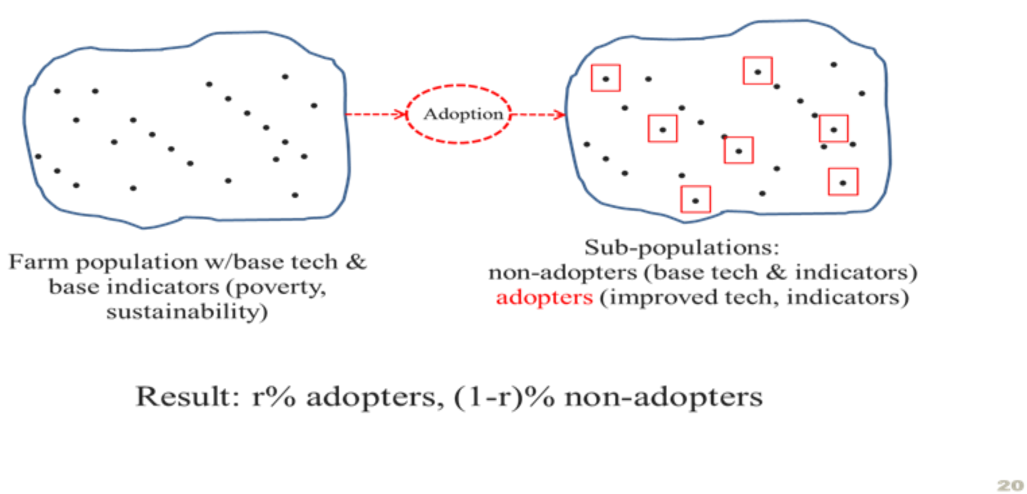
The theoretical framework of the TOA-MD model (Antle, 2011) assumes that, farmers as economically rational people, choose from a set of farm systems that yield positive expected net returns. This model simulates an experiment to compare two systems, referred to as System 1 and System 2. System 1 is the baseline case or the "control" in an experimental design. System 2 is a new system, typically a modification of System 1, or the "treatment" in an experimental design. The economic outcomes associated with each of the two systems are simulated and compared for three different climate scenarios. It is expected that changes in climatic conditions will affect the economic outcomes of the system 1 causing some farmers to adopt system 2 where they will employ improved technology. By so doing, both adopters and non-adopters of system 2 and thus the entire population of farms may gain or lose in terms of changes in their net per farm returns, net incomes and poverty levels.



3.5.1.1.1 Adoption analysis

An adoption process leads to selection of the population into two sub-populations of non-adopters and adopters of system 2. Figure 3.2 shows the logical structure of the TOA-MD.

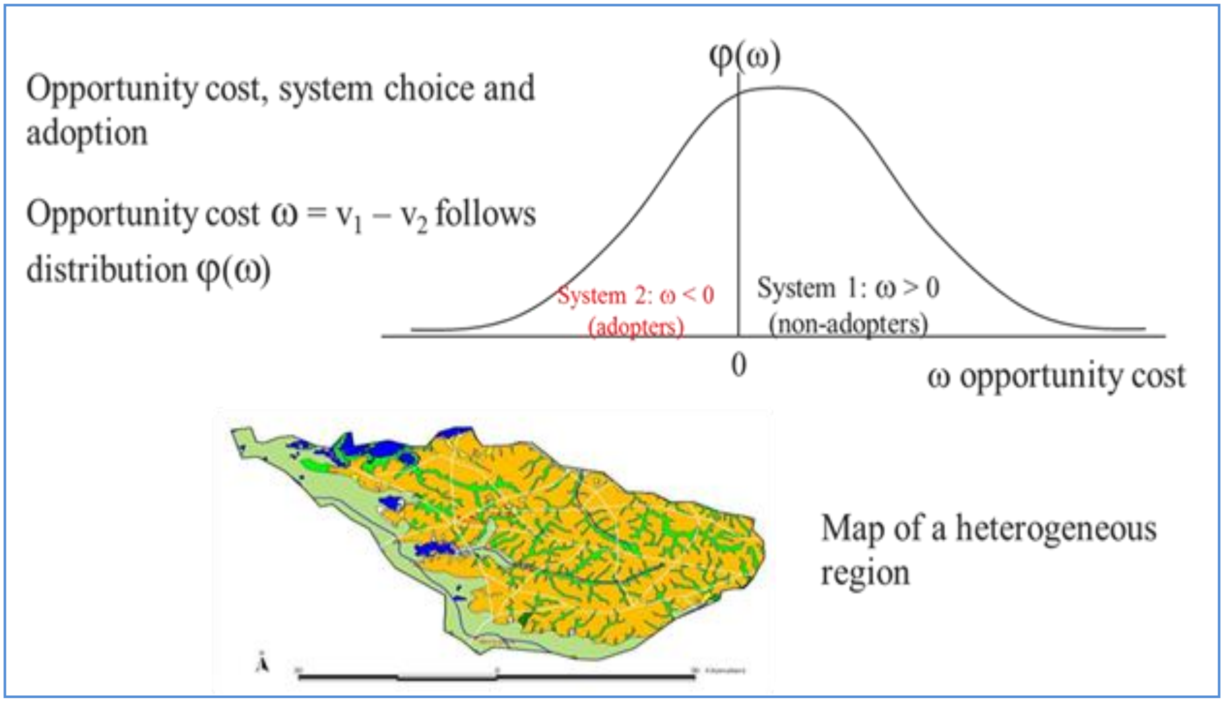
Figure 3.2: Logical structure of TOA-MD: Adoption analysis



Source: Antle and Valdivia, 2011

Adoption is a process through which the population of farms selects itself into sub-populations of non-adopters and adopters. A key feature of this model is that it takes into account the fact that farmers systematically select themselves into sub-population groups (depending on the kind of production systems used by the individual farmers. Analysis shows that this selection must be taken into account to obtain accurate estimates of impact (Antle and Valdivia, 2011). Figure 3.3 shows the system choice and adoption based on opportunity cost.

Fig 3.3: System choice and adoption based on opportunity cost



Source: Antle and Valdivia, 2011

Now suppose that instead of the "base" technology, a new, better-adapted technology is used. In this case:

System 1 = base climate, base technology

System 2 = changed climate, adapted technology

$\omega = v_1 - v_2$; measures the difference in income caused by the change in climate.

Where;

ω = Opportunity cost

v_1 = Expected net returns for system 1

v_2 = Expected net returns for system 2 as shown in figure 3.3

In the TOA-MD model, a farmer at a site s using a production system h earns per-hectare returns equivalent to $v_t = v_t(s,h)$ each season/period.

Let: System 1 = Farms with base technology and base climate, and

System 2 = Farms with adapted technology under changed climate.

Now if $\omega = v_{1} - v_{2}$ measures the difference in income between systems 1 and 2;

then $\omega = v_{1} - v_{2} > 0$, means climate change leads to a gain for farms that continue to use the base technology, but

if $\omega = v_{1} - v_{2} < 0$, then climate change implies a loss for the farms that continue to use the base technology.

When the production system changes for instance from j to k following climate change, the expected economic returns (gain or loss) as a result of this change is given by:

$$\omega(p, s, j, k) = V(p, s, j) - V(p, s, k) \quad (1)$$

Where a positive $\omega(p, s, j, k)$ denotes the loss associated with changing from system j to k while a negative $\omega(p, s, j, k)$ denotes a gain from changing from system j to k.

If we let $\varphi(\omega \backslash p, j, k)$ be the spatial distribution of gains or losses in the population of S farms, the percentage of farms with $\omega(p, s, j, k) < a$ is:

$$r(a, p, j, k) = 100 \int_{-\infty}^{a} \varphi(\omega \backslash p, j, k) d\omega$$

(2)

Where a is returns/ha.

3.5.2 Cobb-Douglas Production Function

In trying to analyze the significant effect of the production inputs on output levels under the current production system assuming no climate change, we saw the need to model a Cobb-Douglas production function. This model was used in estimating the significant effects of the production inputs such as labour, farm size, fertilizer and manure, seed (improved and unimproved), weedicide, pesticides and ploughing cost on output levels; thus, regressing output on the above mentioned variables (the factors of production). The Cobb-Douglas production function model was used to capture the significant effects of the production inputs on output levels under the current production system. Cobb-Douglas production function is one of the production functions that are widely used in agricultural production estimations. This production function is widely used due to its simplicity and ability to provide estimates of the returns to scale. Most theoretical and empirical studies define production as a technical relationship between inputs and outputs. Shepherd (1970) indicates that, the formulation of production functions assumes "firms are technically efficient" and hence defined production function as the relationship between a maximal technically feasible output and inputs needed to produce that output (Mishra, 2007).

3.5.2.1 Theoretical Model

The Cobb-Douglas production function is theoretically specified as;

$$Y = Ax_1^a x_2^b \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

(Cobb and Douglas. 1928) where A is a constant and a and b are elasticity measures. By the Cobb-Douglas model, x_1 and $x_2$are capital and labour. The summation of the elasticity constants gives the returns to scale. For instance, all inputs are scaled up by a factor t, the new level of output function becomes;

$$f(tx_1, tx_2) = A(tx_1)^a(tx_1)^b \ = \ t^{a+b}Ax_1^a x_2^b \ \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

There will be a constant returns if;

$$t^{a+b} = t; a + b = 1 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The Cobb-Douglas production function is often used to analyse the supply side performance and measurement of a country's production potential (Hajkova and Hurnik, 2007).

The practical use of production function requires that certain assumptions on the functional representation of the production technology. One very important assumption made by the Cobb-Douglas is the constant returns to scale. These assumptions restrict the sum of labour and capital elasticities to 1.

3.5.2.2 Empirical Model

$$\log Output = \beta_0 + \beta_1 logfarmsize + \beta_2 \, log\ labour + \beta_3 \, log\ \ fertilizer$$
$$+ \beta_4 \, log\ manure + \beta_5 \, log\ improved\ seed + \beta_6 \, log\ local\ seed$$
$$+ \beta_7 \, log\ weedicide + \beta_8 \, log\ pesticide + \beta_9 \, log\ ploughing\ cost + \mu$$

Where;

$logOutput$ = it is the natural logarithm of the number of bags of maize in kilograms (100kg) per acre plot.

$logFarm\ size$ = it is the natural logarithm of the total number of acres cultivated by a household farmer.

$logLabour$ = it is the natural logarithm of the number of persons working on an acre of farmland.

$logfertilizer$ = it is the natural logarithm of the total number of bags of inorganic nutrient supplement in kilograms (50kg) used by a farmer on an acre of farmland.

$logmanure$ = it is the natural logarithm of the total number of bags of organic nutrient supplement in kilograms (50kg) used by a farmer on an acre of farmland.

$logImproved\ seed$ = it is the natural logarithm of the total quantity of improved seeds (100kg) used by a farmer on an acre of farmland.

$logUnimproved\ seed$ = it is the natural logarithm of the total quantity of indigenous seeds (100kg) used by a farmer on an acre of farmland.

$logWeedicides$ = it is the natural logarithm of the total quantity of chemicals in bottles (1litre) used in controlling weeds on an acre of farmland.

$logPesticides$ = it is the natural logarithm of the total quantity of chemicals in bottles (1litre) used in controlling weeds on an acre of farmland.

$logPloughing\ cost$= it is the total cost (amount in GH¢) used in ploughing an acre farmland.

μ= it is the error term.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section presents and discusses the results of the research work. It gives in depth discussions on the demographic characteristics of smallholder farmers interviewed in SKB. It also discusses the system of farming in the SKB. Temperature and rainfall trends from 1976 to 2011 were established for some selected areas (Bole, Yendi, Tamale, Navrongo and Wa) of Northern Ghana and the results presented in graphs. The Cobb-Douglas production function was used to estimate the effects of the factors of production such as labour, farm size, inorganic fertilizer, manure, improved and unimproved seeds, weedicide, pesticides and ploughing cost on output levels under the current production system with no climate change scenario, while the TOA-MD model was used to analyze the economic outcomes of climate change on peoples' livelihood.

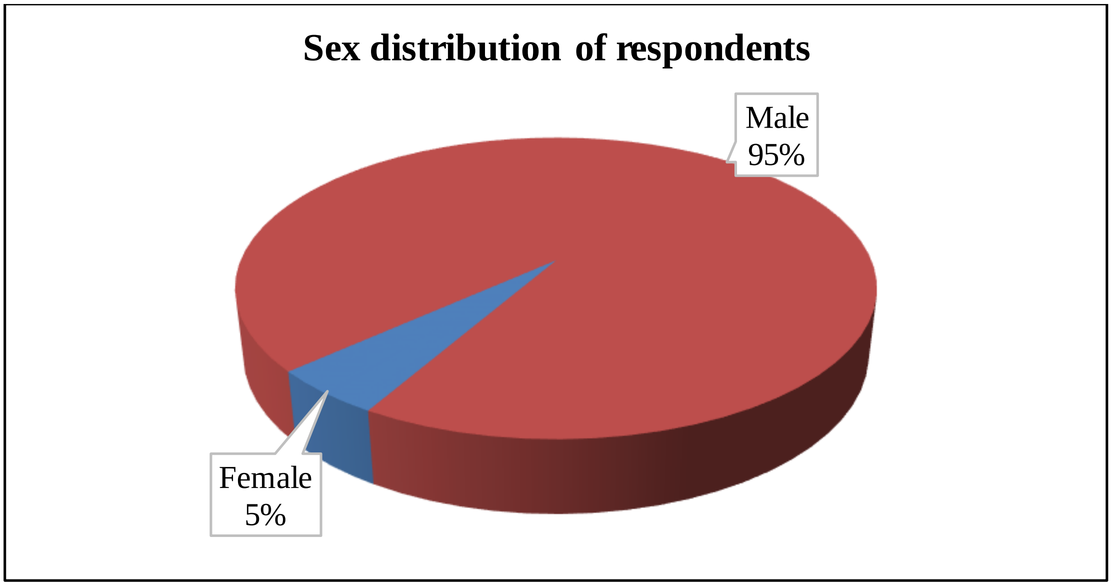
4.1 Demographics of smallholder farmers in SKB

Smallholder farmer demographic data such as sex, age, educational status, occupation and household size are presented to highlight their distributions among the population and to ascertain the level of vunerability or adaptability of the smallholder farmers to climate change.

4.1.1 Sex Distribution

Individuals interviewed represent household heads who own and have full control over the use of land. Majority (95%) of farmers interviewed were males. Only 10 (5%) of the 200 farmers interviewed were females.

Figure 4.1: Sex distribution of respondents



Source: Field survey, 2013/2014

This distribution depicts a phenomenon of land acquisition and use of lands in the NR of Ghana. Sufficient land is available for crop farming and livestock rearing; the acquisition of land for large scale farming is not a problem ((Mamprugu-Moaduri District Assembly, 2013) however; it is a rare case that women own land or have full control over the use of land in the NR. Land management (Laube *et al*., 2011), crops and livestock enterprise in Northern Ghana are male-dominant activities. Women either help their husbands, fathers, brothers or relatives on the farmlands but they do not have full control over farmlands. During the field study, a few women (5%) possess and have full control over their farmlands because they had lost their husbands. Some women had received them as gifts from their husbands to enable them farm and support their household with the returns from the land.

Farmers become more vulnerable when incidence of climate change results in delay in rainfall, pests and disease outbreaks of crops and livestock, flooding, death of livestock and destruction of crops. Farmers become food and income insecure because of decrease or loss in crop produce and livestock. To further worsen the plight of these farmers is the increase in dependency rate of women and children and this could contribute to increase in poverty rate in NR because more of the people will be vulnerable.

4.1.2 Gender, land ownership and wage

Household heads are usually males and are the custodians of household land hence have full control over land use. Generally, women support with the farm activities and supply up to 80% of labour. Despite the critical role women play in agriculture, they have limited access to land (IFAD, 1998; Duncan, 2004).

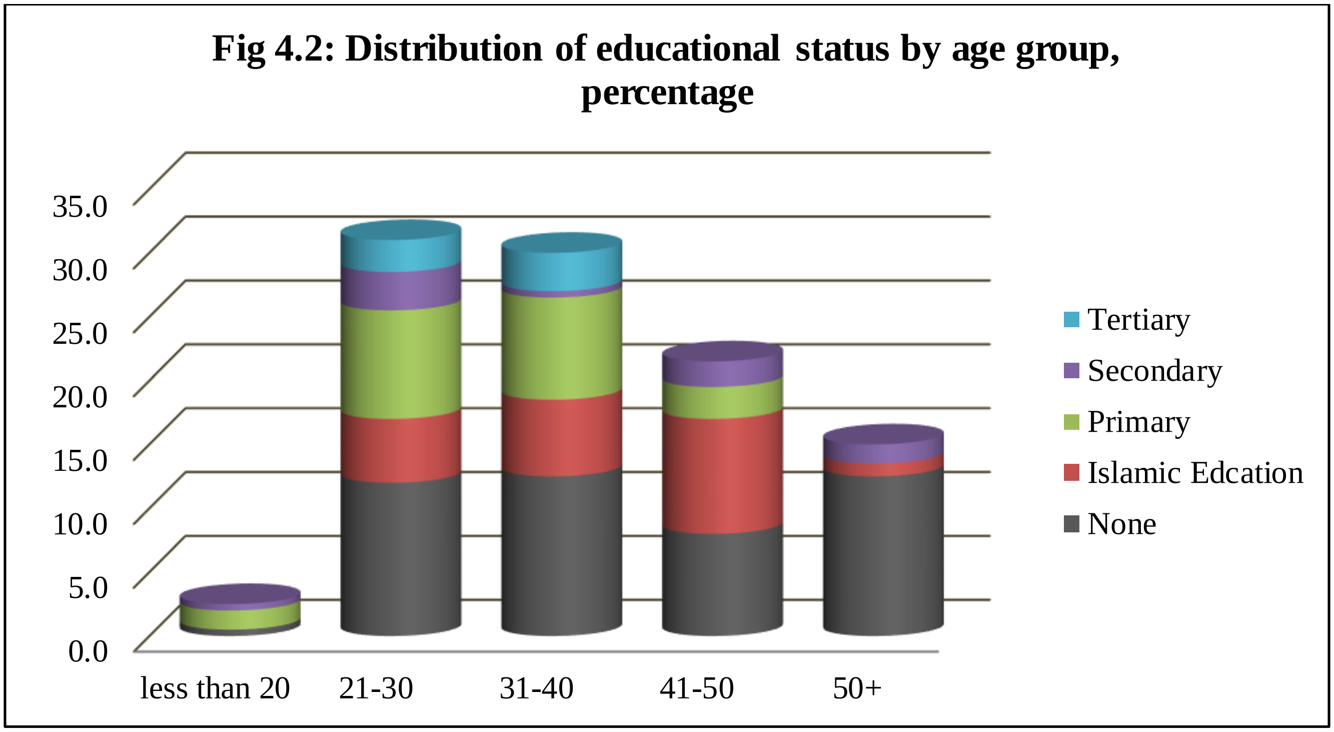
Also, labour wage is gender biased; respondents confirmed that women who are hired as casual labourers are paid a flat rate of GHc5.00 per day and some as low as GHc3.00 whiles men who are hired as casual labourers are paid a flat rate of GHc7.00 to GHc8.00 per day depending on the nature of activity. This was justified by the reason that the quality and quantum of work output by men is higher than that of women, with women requiring relatively more days to complete the same tasks as men.

Climate change as it stands, poses great employment risk in the agricultural sector through job losses, decrease in labour and reduction in wages as well as other social dimensions (such as health, migration and education) and with the increasing consequences of climate change, without adaptation, women will be more vulnerable. In this regard, the agricultural sector will no longer be a dependent source of livelihood and will affects the people's capacity to survive.

4.1.3 Distribution of smallholder farmers by age group and educational status

Age and the educational level of a farmer are important in assessing his/her vulnerability to the impacts of climate change and ability to build resilience against climate change impacts. The age distribution indicates that, the active labour force (61%) who are considered as the youth (21-40years) are much involved in agriculture in the SKB.

Figure 4.2: Distribution of educational status by age group, percentage



Source: Field survey, 2013/2014

Agriculture employs about 70% of the working population in the Northern Ghana (GSS 2002; Laube *et al*., 2011); implying that, agriculture has the potential to absorb more of the Northern populace if the sector becomes more sustainable and lucrative to be able to impact positively on the livelihoods of people and ensure food security in the NR of Ghana. However, the increasing impact of climate change is challenging agriculture to achieve these potentials. It is plausible that majority of the people who are mainly the active labour force (21-40years) will be the ones to exist in the Mid-Century – 2050 to face the severity and consequences of the changing climate.

The NR of Ghana of which SKB is no exception, is one of the three administrative regions in Ghana that are considered as the poorest and food insecure zones in Ghana with poverty rates ranging from 69% to 88% across the region (Shepherd *et al.*, 2005; Nyantakyi-Frimpong, 2013). This therefore implies that, the greater percentage of the people in the NR of Ghana is more vulnerable. Increased incidence of poverty rates, food insecurity and increase cases of unemployment will be rampant because agriculture, without adaptation, will no more by 2050 be sustainable and lucrative to employ the people of the NR as a result of the increasing incidence of the effects of climate change.

About 45.5% of the 200 farmers interviewed in the SKB had no form of education; and 21% had Islamic education commonly known by the people as "Makaranta", about 20.5 had primary level education, about 7.5% had Secondary level education and about 5.5% had tertiary education. It was realized that, the highest frequency was farmers who had no form of education. The second highest frequency was farmers who had Islamic education. The third highest frequency was farmers who had primary education with majority of them having lower education up to primary three. Those with the secondary and tertiary level of education were trained and pupil teachers who were also involved in farming activities, this category of farmers had the lowest frequency.

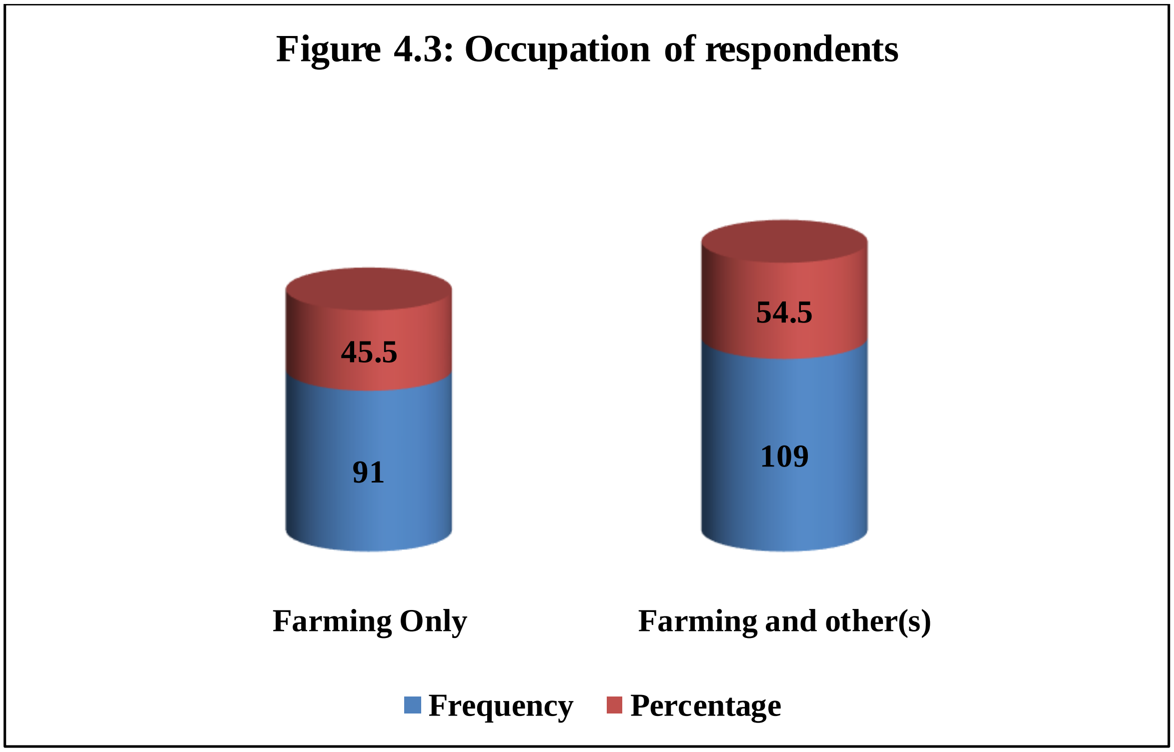
The educational distribution in figure 4.2 indicates that, majority of the people who are involved in agriculture have no form of education and with majority of the remaining categories having lower form of education to the primary level. Higher level of education is believed to be associated with access to information on improved technologies and higher productivity (Norris and Batie 1987; Deressa *et al.*, 2008). Evidence from various studies indicates that there is a positive relationship between the educational level of the households and the adoption of improved technologies (Igoden *et al.*, 1990; Lin 1991; Deressa *et al.*, 2008) and adaptation to climate change (Maddison 2006; Deressa *et al.*, 2008). Therefore, farmers with higher levels of education are more likely to adapt better to climate change; hence less vulnerable. This clearly depicts that, large number of people will be the most vulnerable if incidence of climate change impacts on agriculture aggravates in the NR of Ghana. This is because, majority (87%) of the people have no or low level of education and may lose their sources of livelihood to the consequences of climate change. There may be less or no other dependable sources of income for the majority of the people due to the less or inability of such group of people to move to the other sectors of the economy (industry and service) to seek for employment, and this will have greater impacts on the peoples' livelihood making them poor. Implying that, the NR which has already been pronounced as one of the poorest regions in Ghana will continue to experience increase in poverty and food insecurity levels if smallholder farmers do not adapt good strategies.

4.1.4 Occupation

Crop farming and livestock husbandry are the dominant occupation in the SKB, with the production of cereals and legumes dominating. The main crops grown are maize, cowpea, rice, millet, and groundnut. From the field study, it was revealed that climate change is inseparable from agriculture and for that matter one cannot do farming without experiencing climate change and without causing harm to the environment. Assan *et al.*

(2009) 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 (Marchetta, 2011). Meanwhile, agriculture in Northern Ghana is predominantly climate-dependent; this therefore indicates that there is the tendency of decreased crop yields, increased incidence of crop failure, diseases and pests outbreaks and loss of livelihoods; resulting in increased incidence of food insecurity, malnutrition and poverty; most of the people will become vulnerable especially households that are solely dependent on agriculture. Our field study revealed that, although all the respondents were smallholder farmers, 54.5% were also engaged in non-farm activities to source income to complement that of farming in order to meet their basic needs.

Figure 4.3: Occupation of respondents



Source: Field survey, 2013/2014

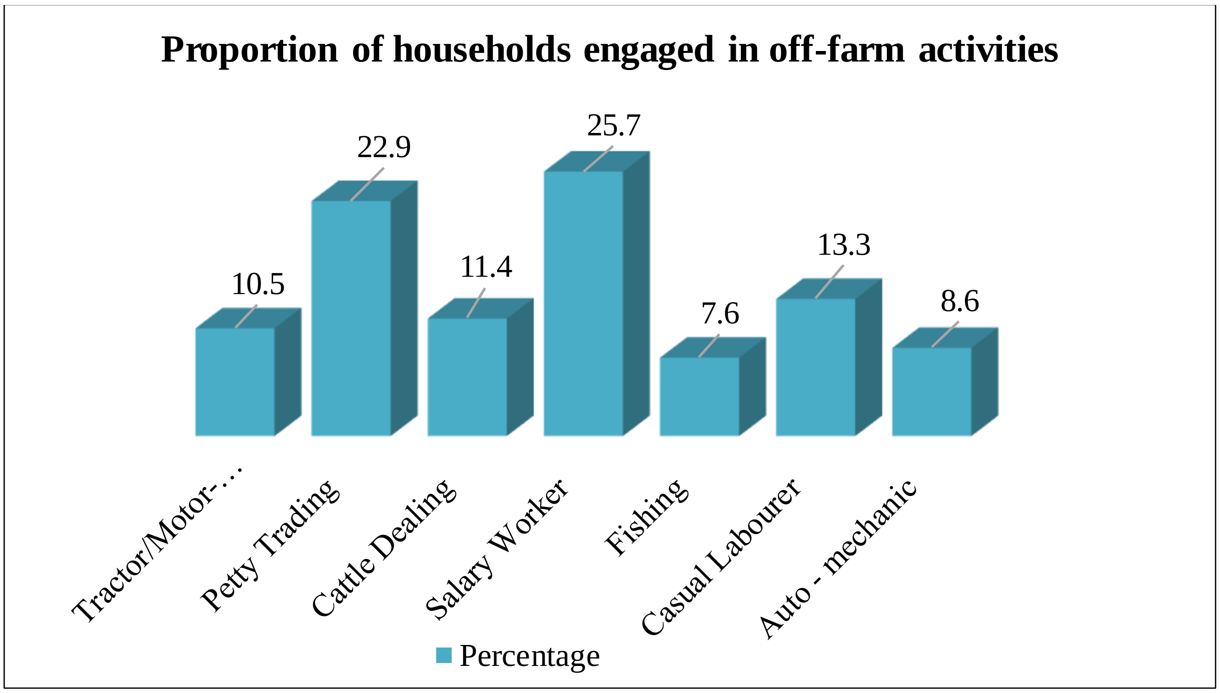
4.1.5 Other Occupation except Farming

The changing climate matters to the poor in Ghana because it would increase the vulnerability of this group by adversely affecting their health, livelihood and undermine growth opportunities crucial for poverty reduction and these poor are mostly found in the rural areas (Nelson and Agbey, 2005). Marchetta (2011) indicated that, households who live in the rural areas of Northern Ghana of which SKB is no exception, base their subsistence on natural resources, which are threatened by the increased frequency of extreme weather events and the progressive desertification in the region and due to this, households engage in non-farm activities to earn additional support for their livelihood. This is what Yaro (2006) termed as "multiplex livelihood adaptation" (Marchetta, 2011).

In Ghana for instance, particularly Northern Ghana, climate change will significantly aggravate water stress, reduce food security, increase impacts from extreme weather events and displace millions of people due to floods (Nelson and Agbey, 2005). Marchetta (2011) added that, there is decline in farm yields almost everywhere in Northern Ghana, and this has induced a widespread increase in non-farm activities that could generate a complementary source of earnings, as farming activities alone has become hardly sufficient to meet the basic needs of the households. The need to earn cash to buy food, clothes and other goods serves as the main factor that lead to the increase in non-farm activities in the NR and this actually serves as a coping strategy to small household farmers.

Household farmers interviewed who had other sources of income were engaged in activities such as petty trading, tractor/motor-king operating, cattle dealing, fishing, casual labour, auto-mechanic and salary earned-work. Some of these respondents were self-employed or employed in the formal sector while others were engaged in casual work. The engagement of smallholder farmers in diverse off-farm activities in order to support their livelihoods, serves as coping strategies to the changing climate.

Figure 4.4: Proportion of households engaged in off-farm activities



Source: Field survey, 2013/2014

4.1.6 Household size

A household is defined as a single person, or a group of people living at the same address who have the address as their only or main residence and either share one main meal a day or share living accommodation or both (http://www.ons.gov.uk/ons/rel/lmac/working-andworkless-households/2013/table-f.xls, 25th August, 2014). Household sizes of respondents ranged from one to as many as thirty persons. About 94.5% of respondents have households of more than 5 persons (See table 4.1).

Table 4.1: Household size Distribution of respondents

Household size	Frequency	Percentage
1 – 5	11	5.5
6 – 10	61	30.5
11 – 15	57	28.5
16 – 20	32	16
21 – 25	24	12
26 – 30	15	7.5
Total	200	100

Sources: Field survey, 2013/2014

About 64% of household heads (respondents) have more than 10 dependents (who may be children, wives and/or relatives). The social dependency in the study area is clearly high. Household heads are therefore faced with pressure to make more income or profit in order to cater for their households. Even though household heads would have more hands to work on the farms, they would also have more mouths to feed and cater for. The increased incidence of climate change and its negative impacts on crop and livestock yields jeopardizes the future of food security hence places small-scale farm household heads into vulnerable positions in providing for their family's basic needs such as food, clothing, shelter and health care.

It was also revealed that, the demands on most household farmers who have very little income are extremely high since they have to secure the livelihood of their family members. The reality, for instance, highlights one correlation; the less income and the more children mostly leads to the fact that only a few children in the family can have a chance to higher education and this confirms the findings of Müller-Kuckelberg (2012). The current dependency ratio will limit resources available for household heads thereby impeding their capacity to adapt. Land as a resource will be limited because population has the potential to rise. Smallholder farmers will therefore be faced with the challenge to adapt farming practices like mixed farming, crop rotation or land rotation which would help reduce the impact of climate change and in so doing build their resilience. Also, due to high dependency rate, smallholder farmers will be challenged to adapt strategies that are capital intensive such as mechanized agriculture and irrigation.

4.1.7 Agriculture in the SKB

Crop cultivation and livestock rearing are the major source of employment for the populace. SKB lies in the Guinea Savannah agro-ecological zone which has just one rainy season, starting in April/May and ending in September/October, followed by a dry season that lasts for the remainder of the year. Fluctuations in the rainfall patterns and corresponding changes in food availability, has led farmers in Northern Ghana to develop intricate strategies to adapt. During the dry season, agriculture is almost impossible due to lack of water in many parts of Northern Ghana. However, lands along main rivers such as

Sisili-Kulpawn, offer fertile conditions and draw many farmers to farm even during the dry season. During the wet season, only the more elevated areas (uplands) are suitable for agriculture; the lowlands get flooded. As a result of this variability in the climate, farmers often lose a large proportion of their crop yield to either drought or flooding.

4.1.8 Farming systems and major crops

Respondents were predominantly smallholder farmers growing a wide range of rain-fed crops including maize, cowpea, rice, millet and groundnut. A rotational bush fallow system was a common practice.

4.1.8.1 Early-season cropping

An Early Season cropping is done in March/April at the lowlands along the river. Cowpea and maize are the most cultivated during early cropping season. Crops cultivated at the lowlands are harvested before the peak of the rains in July/August, as low laying lands get flooded. At this period (July/August), cultivation is done on upland fields. The early season on the uplands stretches to the month of November. Almost all the smallholder farmers engage in early-season cropping. Of the total small farm households, 98.5% are engaged in early-season cropping.

4.1.8.2 Late-season cropping

In the months of September/October, the floods at the lowlands recede making way for a second crop within the same year. This is referred to as late-season cropping. This period is followed by the harmattan (dry season) which begins in December/January. Again, almost all the smallholder farmers engage in late-season cropping. Of the total small farm households, 95.5% are engaged in late-season cropping.

The practice of smallholder farmers in the SKB where more than a single cropping is done during a farming season serves as a coping strategy to the changing climate (field survey, 2013/2014). Almost all the smallholder farmers interviewed were engaged in more than a single cropping across different locations. Of the total small farm households, 97% were engaged in more than single cropping; cultivating crops like maize, cowpea, groundnut, millet and variety of vegetables. Studies indicate that, in order to reduce risk in agricultural production, smallholder farmers must cultivate different crop types across different growth periods and with diverse moisture requirements, and in different locations (compound farm, family farm, bush farm) with different soil types to increase the chance of at least some crops surviving under extreme weather conditions (Tonah, 1993; Laube, 2007).

Table 4.2: Distribution of farmers by crop; crop area cultivated on lowlands and uplands

Crop	Farmers		Lowland (Acres)	Upland (Acres)	Total Area (Acres)
	Freq.	%			
Maize	193	96.5	1,212.0	689.0	1,901.0
Cowpea	192	96.0	1,010.8	146.5	1,157.3
Rice	26	13.0	277.5	-	277.5
Millet	18	9.0	-	78.0	78.0
Groundnut	11	5.5	7.0	21.5	28.5
Total			**2,507.3**	**935.0**	**3,442.3**

Sources: Field survey, 2013/2014

Rice is one of the staple crops grown in the SKB but unlike maize and cowpea, rice is very sensitive to climate, environmental and soil conditions. Unfavourable changes in climatic factors such as temperature, precipitation, relative humidity and sunshine duration are expected to affect rice yield adversely (Mabe *et al.*, 2012).

Rice cultivation in the study area is a high risk enterprise due to the possibility of flooding. Perennial flooding by the Sisili-Kulpawn River destroys rice farms in low lying areas. This is a major disincentive in rice cultivation in the study area. Moreover, erratic rainfall pattern which results in delay in rains as a result of the changing climate discourages smallholder farmers who cultivate rice. Our study revealed that, out of the 200 smallholder farmers interviewed, only 26 (13%) farmers cultivate rice covering an area of 277.5 acres (See table 4.2) with an average paddy yield of 262.03 kg per acre. The average rice paddy yield is far below what was reported by Angelucci *et al.* (2013); rain-fed rice generates average paddy yields of 404.69 to 971.27kg per acre. This therefore is a clear indication why smallholder farmers in the SKB are discouraged to cultivate rice.

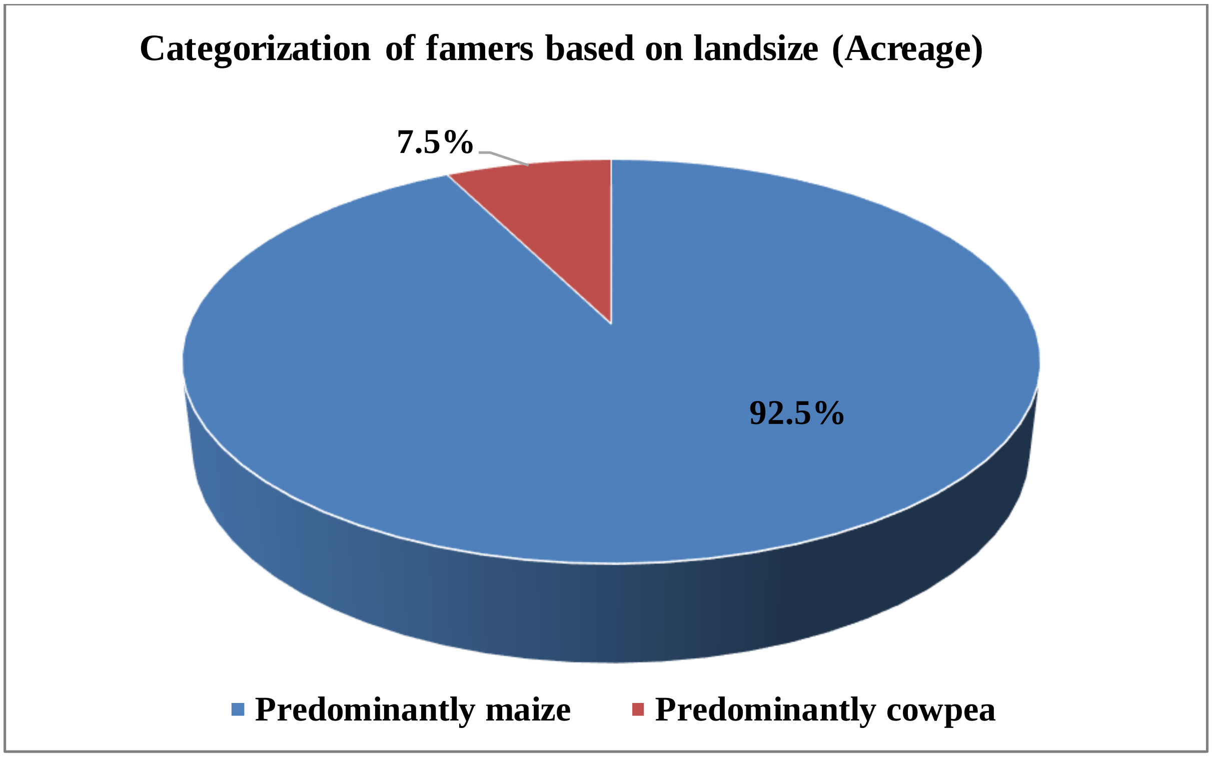
Other crops such as millet, soybean, groundnut, pepper, tomato, watermelon, garden eggs and okra were recorded during the survey. Apart from watermelon, the remaining was cultivated for the household's consumption.

The choice of crops cultivated often indicates the amount of risk the farmer is willing to accept. Most households, whether they had lowlands or uplands, were more risk averse and often chose crops accordingly. Farms are usually divided by classes according to their productivity; compound farms also known as upland farms and bush farms also known as lowland farms: the most valuable continuously cultivated (Blench, 1999).

About 97.5% of the farm household population interviewed, held lowlands of about 2,507.3acres and uplands occupying land stretch of about 935acres. Our field study confirmed that, ample land was available for crop farms and the acquisition of land for farming was not a challenge. This indicates that, farmers have the potential to increase their productivity through increasing the size of farmlands, *ceteris paribus*.

Considering the systems of farming, smallholder farmers were categorized under two farm activities to be used for the current and future systems of impact analysis. These two activities are; predominantly maize (activity 1) and predominantly cowpea (activity 2).

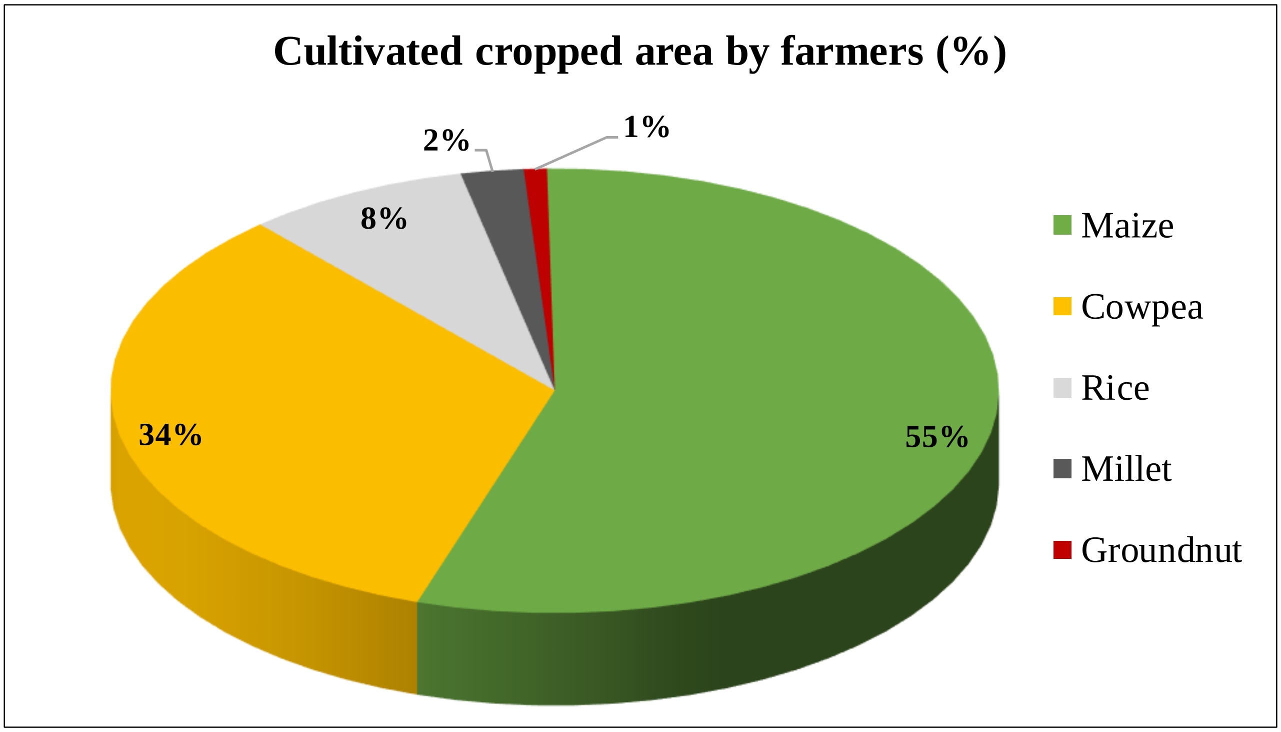
Figure 4.5: Categorization of famers based on land size (Acreage)



Source: Field survey, 2013/2014

The stratification was based on the land size (in acres) used for the cultivation of either of the major crops, cowpea and maize. Maize-based system to the system where a farmer cultivates both maize and cowpea but apportion relatively large land size (in acres) for the cultivation of maize than cowpea whereas cowpea-based system refers to the system whereby farmers cultivate both maize and cowpea but apportion relatively large land size (in acres) for the cultivation of cowpea than maize. About 173 (92.5%) of the 187 farmers identified to cultivate both maize and cowpea, were predominantly maize with the remaining 14 farmers (7.5%) being predominantly cowpea farmers. In general, farmers in the research area can be classified as predominantly cereal farmers thus, 1,901.0acres (55.2%) of the total cultivated land area was cropped with maize, 277.5acres (8.1%) was cropped with rice and 78.0acres (2.2%) was cropped with millet (See table 4.2; figure 4.6).

Figure 4.6: Cultivated cropped area by farmers (%)



Sources: Field survey, 2013/2014

4.1.9 Farm cultural practices

During the field study, it was realized that farmers usually start with clearing or ploughing of farmlands (this depends on the type of crop to be cultivated) and end with transportation of produce to homes for storage, consumption or marketing. Farmers interviewed indicated that they either employ casual labour or use family labour to execute these above mentioned activities. Of the 200small farm households, 8.5% used family labour whereas the majority 91.5% employed casual labour. In view of this, activities for the cultivation of the dominant crops (maize and cowpea) are elaborated. For the cultivation of maize, farmers reported starting with ploughing followed by sowing, fertilizer application, herbicide application, weeding, harvesting, shelling / threshing and finally with transportation. Also, for the cultivation of cowpea, farmers reported starting with harrowing/clearing followed by sowing, herbicide application, continuous application of pesticide/insecticide, weeding, harvesting and finally with transportation.

4.1.9.1 Cultural Practice for Maize cultivation

A total of 1,901acres of maize was cultivated by the 193farmers as indicated earlier. Of the total maize area, 92.5% (1,758acres) was ploughed before planting and 77.7% (1,477acres) was seeded with improved variety referred to as Pannar.

Weed control was largely done by herbicide application. Of the total maize area, 96.2% (1,828acres) was applied with herbicide either before or after planting. About 95.4% of this area received pre-emergence herbicide whereas 43.7% received both pre-emergence and post-emergence application of herbicide.

Pesticide application however, is not a common practice in maize cropping in the study area. About 96.4% of the maize farmers interviewed applied no form of pesticide.

Of the total maize area, 87.3% (1,660.5acres) was applied with inorganic fertilizer at an average rate of 47.9kg per acre. A compound fertilizer, NPK was applied as basal by side placement one to two weeks after sowing. Sulphate of Ammonia or Urea was top-dressed four to five weeks after sowing.

4.1.9.2 Cultural Practice for Cowpea cultivation

A total of 1,157.3acres of cowpea was cultivated. Cowpea cultivation usually follows maize cultivation on the same piece of land hence clearing and/or harrowing of the field may proceed sowing. Of the total cultivated land area, 56.1% (649.2acres) and 26.1% (302.4acres) was cleared and harrowed respectively. Improved seed technology have been widely accepted and used by the smallholder farmers; 93% (1,076.8acres) of cowpea area was seeded with improved cowpea variety referred to as Alan cash.

Weed control in cowpea was also largely done by chemical means. Of the total cowpea area, 75.5% (873.8acres) was applied with herbicide in control of weeds at an average rate of 1.9litres per acre. About 74.3% (859.9acres) of this area received pre-emergence herbicide whereas 4.8% received both pre-emergence and post-emergence application of herbicide.

Farmers reported that insect pest was a major problem in cowpea cultivation; hence pesticide application was a common practice among cowpea farmers and it was done frequently until harvest. About 86.8% (1,004.3acres) of the total cowpea area received pesticide.

None of the farmers applied inorganic fertilizer to their cowpea fields. This is because, cowpea is a nitrogen-fixing crop and does not require too much nitrogen fertilizer because its roots have nodules in which soil bacteria called Rhizobia help to fix nitrogen from the air.

Table 4.3 reports the farm size, output levels, input costs and revenues for the major staples (maize, cowpea, rice, millet and groundnut) cultivated in the SKB.

Table 4.3: Acreage of major crops cultivated and their respective outputs, costs and revenues per acre

Crop	Farm Size (acre)	Output (kg/acre)	Cost (GHS/acre)	Revenue (GHS/acre)	Net (GHS/acre)
Maize	1,901.0	313.15	154.20	132.42	-21.78
Cowpea	1,157.3	186.47	139.14	371.24	232.1
Rice	277.5	262.34	173.51	150.09	-23.42
Millet	78.0	129.49	105.95	108.53	2.58
Groundnut	28.50	259.64	61.70	127.02	65.32

Sources: Field survey, 2013/2014

The study revealed that smallholder farmers spent an average of GHS 154.20 per acre on variable cost for the production of maize and had an average return of GHS 132.42 per acre. An average net revenue of GHS -21.78 was obtained per acre. Of the 193 maize farmers interviewed, 56.5% had negative net revenues indicating that they spent more on production but had relatively less in return.

With respect to cowpea production, smallholder farmers spent an average of GHS 139.14 per acre and had an average return of GHS 371.24. An average net revenue of GHS 232.10

was obtained per acre. Of the 192 cowpea farmers interviewed, 81.8% had positive net revenues indicating that they spent less on production as compared to their returns.

For the production of rice, farmers spent an average of GHS 173.51 per acre and had an average return of GHS 150.09. An average net revenue of -23.42 was obtained. Out of the 26 rice farmers, 69.23% had negative net revenues; these percentages of farmers spent more on production but relatively had less returns. Millet and groundnut were cultivated by a few farmers. Farmers spent an average of GHS 105.95 and GHS 61.70 per acre for the production of millet and groundnut respectively. An average return of GHS 108.53 and GHS 127.02 were obtained respectively resulting in net revenue of 2.58 and 65.32.

Farmers in SKB are predominantly cereal farmers as indicated in the earlier discussion. However, the production of these cereal crops were not profitable (indicating a greater loss) as compared to the production of leguminous crops (See table 4.3).

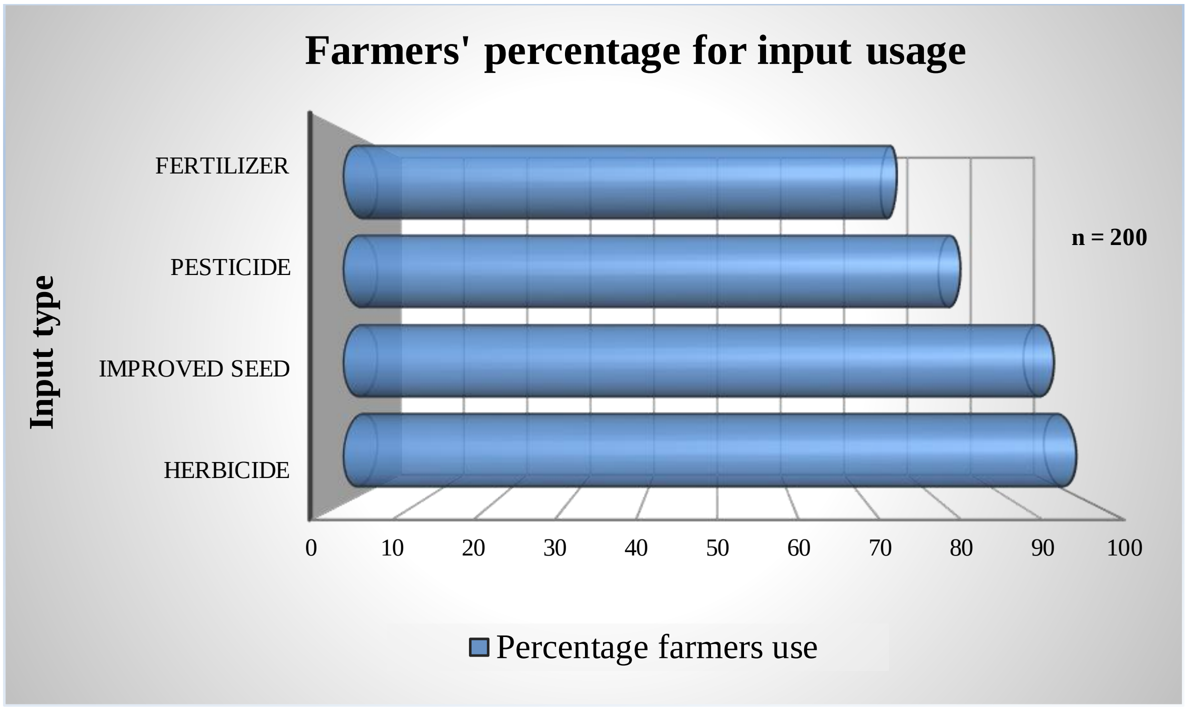
4.1.10 Use of Agro-inputs

Fertilizer, herbicides, pesticide/insecticides and improved seeds are the major agro-inputs used by small scale farmers in the SKB. The use of farm inputs has been strongly driven by the passing enthusiasms of agricultural development projects (Blench, 1999). The right combination of these inputs is necessary for maximum yields.

Table 4.4: Percentage of farmers using different inputs (n = 200)

	Fertilizer	%	Pesticides	%	Improved seeds	%	Herbicides	%
Yes	148	74	165	82.5	190	95	196	98
No	52	26	35	17.5	10	5	4	2

Figure 4.7: Farmers' percentage for input usage



Source: Field survey, 2013/2014

4.1.10.1 Use of fertilizer and manure

The use of inorganic fertilizer was more common compared to the use of organic manure despite the presence of abundant livestock and manure in the SKB. Of the total small farm households, 74% applied inorganic fertilizer once or twice to their crops whiles 9% applied organic manure. The application of inorganic fertilizer, however, is limited to upland fields. The Mamprugu-Moaduri District Assembly (2013) explains that, the floods leave behind fertile soils in the lowlands needing no application of fertilizer. Ragasa *et al.* (2013a) indicated that, the recommended rates of fertilizer depend on the agro-ecological zone, soil type, and cropping history. They reported that, the recommended application rates for either starter (basal) or side-dress (top-dress) fertilizer applications range from 50-150kg each per an acre for maize. Ragasa *et al.* (2013b) reported that, the application rates recommended by CSIR and MOFA are 26.3 kilogram/acre of nitrogen for rice cultivation in the forest zone with less than five years of fallow period and 40.5 kilogram/acre of nitrogen for rice plots that are continuously cropped.

A total farm area of 1,890.5acres received inorganic fertilizer application; 1,660.5acres of maize area at an average application rate of 47.9kg per acre and this is below the recommended application rate range 50-150kg. With regards to rice, 230.0acres of farm area received inorganic fertilizer at an average rate of 56.5kg per acre. Cowpea, millet and groundnut farms received no inorganic fertilizer. Though no cowpea farmer applied inorganic fertilizer in the SKB, it is recommended in Dugje *et al.* (2009) that, the average application rate of compound fertilizer – NPK 15:15:15 (6.1 kg of Nitrogen) is 40.5kg/acre as a starter application and that of single super phosphate –SUPA (12.2kg of SUPA) is 40.5kg/acre. This implies that, cowpea farmers would have increased their output through the application of inorganic fertilizer at the recommended rate.

4.1.10.2 Use of herbicides

Herbicide is widely used among the smallholder farmers in the study area. About 98% of respondents applied herbicides on a total land area of 2,817.9acres with maize area (1,828acres) receiving the highest quantity followed by cowpea area (873.9acres), millet area (52acres), rice area (48.5acres) and groundnut area (15.5acres). The control of weeds with weedicides is cheaper, more efficient and faster than manual weeding. Production cost is reduced, crop yield is improved by the timely absence of weeds, and hence farm profitability and farmers livelihood are improved. Ragasa *et al.* (2013a) reveal that, the average application rate of herbicide for maize farm is 3.7 litres per acre with a recommended rate ranging 2.4 – 3.6 litres/acre but the Northern Savannah zone has an average application rate of 2.1litres/acre. We found out that, an average of 1.9litres of herbicide was applied per acre of maize farm which is below the Northern Savannah zone's average. However, 11.4% of these maize farmers applied herbicide above the recommended rate of 2.4-3.6litres/acre. The average application rate of pre-emergence herbicide in cowpea was 1.8litres/acre whereas that of post-emergence is 1.5litres/acre, both of which are above the recommended application rates of 1.6litres/acre for pre-emergence herbicide and 1.2litres/acre for post-emergence according to Dugje, *et al.* (2009). This therefore is an indication that, on the average, smallholder farmers in the SKB overuse herbicides for the cultivation of cowpea and this have consequences on produce, the environment and the soil ecosystem as well as the health of these farmers.

4.1.10.3 Use of improved seeds

The use of improved seeds offers farmers the opportunity to increase their yield. This technology has been accepted by majority of farmers in the study area; this is reflective in the number of respondents who sowed improved seeds and the acreage of cultivated land seeded with improved seeds (See table 4.4). About 95% of the farmers used improved seeds on a land area of 2796.3acres (81.2% of the total cultivated area). The use of improved seeds was however limited to maize, cowpea and rice; 1,477acres of maize area being the highest followed by cowpea (1076.8acres) and rice (242.5acres).

Table 4.5: Percentage of farmers using Improved/Unimproved variety

Crop	Improved variety		Unimproved variety		**Total**	
	Farmers (Freq.)	Area (acre)	Farmers (Freq.)	Area (acre)	Farmers (Freq.)	Area (acre)
Maize	141	1,477.0	52	424.0	193	1,901.0
Cowpea	175	1,076.8	16	80.5	192	1,157.3
Rice	23	242.5	3	35.0	26	277.5
Millet	-	-	18	78.0	18	78.0
Groundnut	-	-	11	28.5	11	28.5
TOTAL		**2,796.3**		**646.0**		**3,442.3**

Sources: Field survey, 2013/2014

Of the total areas under the cultivation of maize, rice and cowpea, 77.7%, 87.4% and 93.0% were respectively planted with improved seeds. The improved maize variety used by the farmers was referred to as “Pannar”. In combination with the recommended quantity of fertilizer and the right agronomic practices, the Pannar variety is high yielding. The improved cowpea variety cultivated by the farmers has white seed which are relatively larger than the unimproved varieties. Farmers named the improved cowpea variety, *Alan Cash*, because they claimed it is high yielding and has a high market value. "Mandee" is an early maturing variety of rice cultivated in the SKB.

4.1.10.4 Use of Pesticides

About 82.5% of farmers interviewed applied pesticides on a total land area of 1,102.8acres; 1,004.3acres of cowpea, 75.5acres of maize, 10.0acres of millet, 10.0acres of rice and 3.0acres of groundnut area. Application of pesticide on cowpea was a common practice and was considered by the farmers as a necessity considering the level of damage insect pest cause to cowpea.

The average pesticide application rate was 3.1litres per acre. However, some of these cowpea farmers applied above the average rate. Of the 165 cowpea farmers who applied pesticides, 43.6% applied above the average application rate to as much as 14litres per acre whereas 55.8% applied below the average application rate.

For a good crop of cowpea, Dugje *et al.* (2009) reported that, it is required to apply 2–3 sprays of pesticides and this they say is dependent on the severity of insect pest attack and also on the cowpea variety. The recommended application rate of pesticide is 0.16-0.32litre/acre, so for 2-3 sprays implies a range of 0.32-0.9 6litres /acre.

Comparing pesticide application rates by farmers at the study area to the recommended rates suggests that, the farmers are really overusing pesticides. This is of greater concern since such chemicals pose threats to the farmers' health, soil ecosystem, beneficiary insects and the environment at large.

4.1.11 Effect of production inputs on output levels

Increase population and competition for land and its impact on agricultural productivity has led farmers to engage in different production practices. The study therefore saw the need to analyze output levels of the farmers by estimating the production inputs that influence output levels under the current production or climatic environment. The research therefore estimated a Cobb-Douglas production function that allows for the estimation of production elasticity coefficients as well as the effect of input used on output levels under the current production system.

The study used a crop aggregated data; comprising of maize, cowpea, millet, rice, and groundnut, implying that, the production inputs are as well aggregated. The coefficient of determination (R^2) value was 77%. This value implies that, the variation in labour, farm size, fertilizer and manure, seed (improved and unimproved), weedicide, pesticides and ploughing cost explains about 77% of the variation in output levels. The F-statistic indicates that, the overall regression is significant at 1% meaning that the independent variables (inputs) jointly affect output levels.

From the result, we obtained a return to scale value of 0.82. This means that the farmers are operating in the first stage of the production function indicating that, the production function has an increasing returns to scale. Thus, as total input usage increases, output increases more than proportionate increase in the inputs. In other words, farmers have the potential to increase their input usage level needed for an acre of land. Farmers therefore need to scale-up their usage per an acre of land in order to reap the maximum gains from these inputs used. All variables except unimproved seeds and pesticides were significant in the model.

Table 4.6: Cobb-Douglas Production Function Analysis

Variable	Coefficient	Standard error	T-Value	P-Value
Constant	2.218***	0.164	13.510	0.000
Farm size	0.488***	0.156	3.130	0.002
Labour	0.189**	0.082	2.310	0.022
Improved seeds	0.158**	0.069	2.290	0.023
unimproved seeds	0.053	0.034	1.540	0.125
Herbicides	0.158**	0.070	2.240	0.026
Fertilizer	0.073***	0.023	3.120	0.002
Manure	-0.179***	0.068	-2.650	0.009
Pesticides	0.039	0.045	0.870	0.386
Ploughing cost	-0.161**	0.074	-2.170	0.032

F (9, 189) = 27.43   Prob. >F = 0.000 R-squared = 0.7664   Adj. R-squared = 0.7457

NOTE: **** and ** indicates significant levels at 1 percent and 5 percent respectively.*
Dependent Variable: Natural logarithm of output; log (Output); Method: Ordinary Least Squares

The estimated coefficient of farm size was not only significant at 1% but also positive. This means that, there is the possibility of increasing output as a result of increasing farm size. From the research, it was noted that, the acquisition of land for cropping was not a challenge. Also, farmers have sufficient lands that they do not use for production, thus, there is the opportunity for the farmers to increase their farm sizes in order to increase output, *ceteris paribus*. The estimated coefficient of 0.49 means that with an additional acre of farm size, output will increase approximately by half.

The various crop production activities involve the use of labour. This means that labour is an important factor in the production process. From the result, we obtained a positive coefficient for labour and also significant at 5%. The elasticity obtained was 0.19; an indication that a 100% increase in labour has the potential to increase output by 19%. The implication of this finding is that farmers can increase their labour usage and this will translate into a higher output, *ceteris paribus*.

Improved seeds was significant at 5% and also with a positive coefficient. With the changes in the global climate under which production takes place, farmers in the NR need to adopt crop varieties that have the adaptive capacity to adjust to the changing climate. Dugje *et al.* (2009) indicates that, selected crop variety must suite the particular agro-ecological zone, the prevalent climatic conditions (i.e. high climatic resistance) and also suite the cropping system. The crop variety must have attributes like heat tolerance, early maturing, drought tolerance, resistance to pests and diseases, high yield and responsiveness to day length. This becomes more necessary for smallholder farmers to adopt these improved types of seeds, considering the fact that this part of the country has a unimodal rainfall pattern whiles food insecurity and poverty are reported to be predominant. From the result, a 100% increase in improved seeds have the potential of increasing output by 16%, this is therefore a greater opportunity for farmers to increase their yields through the adoption of improved seeds.

With the tedious nature of weeding, farmers prefer using the herbicides/weedicides to manual weeding (using hoes and cutlasses). The respondents noted that, the use of weedicides is more effective than manual weeding. Our research findings with regards to the costs of weeding and the use of herbicides confirms the findings of Ragasa *et al.*

(2013a) that; comparisons with weeding costs suggest that farmers using herbicide have lower costs (145 GHS/acre) than those not using herbicide and had to hire more labor for weeding (207 GHS/acre). From the result, herbicides had a positive significant coefficient of 0.16 at 5%.

Both inorganic fertilizer and manure were significant in the model at 1%. Inorganic fertilizer had a positive coefficient whilst manure (which is predominantly cattle dung) had a negative coefficient. The average application rate of manure was found to be 19 kg per an acre of farmland. Research done by Anane-Sakyi *et al.* (2013) reveals that, organic manure (cow dung) only applied at the rate of 1,619 kg and 3,238 kg per acre of farm did not significantly increase yield. However, at the same rate when combined with inorganic fertilizer, increase in yield was significant. This clearly shows that the application rate of manure per an acre of farm in the SKB was very low (19 kg/acre); an indication why the application rate of manure did not significantly increase output. Smallholder farmers could therefore increase the use of manure as recommended in combination with inorganic fertilizer in order to significantly increase yield.

With regards to fertilizer, the elasticity obtained was 0.07; an indication that the gain from a 100% increase in fertilizer is 7%. The findings of Ragasa *et al.* (2013a) revealed that, in the Northern Savannah zone, the yields between plots with fertilizer applied and plots with no fertilizer applied were significantly different – a particular case of maize crop. When combined with certified seed and herbicide, plots with fertilizer have significantly higher yields (2 tons/hectare more) than those without fertilizer in the Northern Savannah zone, but show no significant difference in other zones in the country. The seemingly more responsive yields to fertilizer use in the Northern Savannah zone can be attributed to lower soil fertility in this zone compared to zones in the Southern zones of the country. This implies that, farmers in SKB can increase their fertilizer usage vis-a-vis the use of improved seeds and herbicides and it will translate into a higher output, *ceteris paribus*.

Holding all other factors constant, ploughing cost had a negative effect on output. This is plausible because as the cost of ploughing increases, farmers are more likely to reduce the number acres they plough or reduce the number of acres a farmer would cultivate and this could hinder the farmers' ability to cultivate on large scale.

4.1.12 Livestock

Whitehead (2006) indicated that, the rearing of cattle, goats, sheep, pigs and different varieties of poultry is increasingly integrated into crop cultivation, as it (Whitehead 2006; Yirga 2007) provides animal traction and manure required for soil fertility maintenance. Yirga (2007) also added that, livestock plays a very important role by serving as a store of value (Deressa *et al.*, 2008). Livestock rearing serves as important nutritional needs and is seen as a coping strategy in case of food shortages that may occur as a result of droughts or floods, although in many poor households they regularly occur in the rainy season before harvest, and so the animals are sold to purchase food items during these times (Tonah, 1993: 142; Adams *et al.*, 1998a: 268; Laube *et al.*, 2011). This study revealed that livestock rearing is predominant in the SKB. Out of the 200 crop farmers interviewed, 180 farmers (90%) are also engaged in a kind of livestock rearing. Most of these farmers reported that they perceived livestock rearing not only as farming but also, as a way of life which serves as source of income generation throughout the year especially during the dry season. Deressa *et al.* (2008) indicates that livestock ownership represent wealth. Smallholder farmers therefore have the potential to increase their wealth under climate through the use appropriate systems of rearing livestock.

Livestock types reared in SKB include; cattle, goat, sheep and poultry (guinea fowl and chicken). The acquisition of land for large scale farming is not a challenge as indicated in the earlier discussion; household farmers could obtain ample lands for livestock rearing. Out of the 200 household farmers interviewed, 54.5% were involved in the rearing of cattle. These percentages of farmers were also engaged in the trading of cattle within and beyond the SKB. 70% of the farmers were involved in the rearing of goats whereas 34% were involved in the rearing of sheep. Farmers interviewed indicated that goat meat is highly consumed by many people and therefore highly patronized than it counterpart sheep; the reason why most farmers rear goats than sheep. About 74.5% of the farmers were involved in the rearing of poultry. It was realized that, households depended mostly on the poultry they rear as sources of meat than given them out for sale. Table 4.7 shows the incidence of livestock ownership by species;

Table 4.7: Incidence of livestock ownership by species

Species	With	%
Cattle	109	54.5
Goat	140	70
Sheep	68	34
Poultry	149	74.5

Sources: Field survey, 2013/2014

The system of rearing livestock in the SKB is predominantly extensive. Farmers reported that, during the dry season, feed for livestock becomes scarce. Grazing animals like cattle, travel long distances to get food and water and as a result, they end up destroying peoples' farms, properties and water bodies. Moreover, animals lose body weight and therefore do not fetch much revenue for the farmer when sold. Farmers reported to incur cost on feeding of livestock during the dry season. Farmers added that, the year 2013 production season was a peculiar case for death of livestock through disease outbreaks. Table 4.8 shows the types of livestock reared in the SKB with their respective units, outputs, average costs and revenues.

Table 4.8: Units of major livestock, their respective outputs, costs and revenues per farm

Type	Unit	Outputs	Cost (GHS/farm)	Revenue (GHS/farm)	Net Revenue (GHS/farm)
Cattle	1,819.0	216.0	754.18	2,367.11	1,612.93
Goat	1,244.0	337.0	35.08	323.09	288.01
Sheep	574.0	137.0	60.71	652.01	591.3
Poultry	3,244.0	1,002.0	44.95	126.45	81.5

Sources: Field survey, 2013/2014

Livestock production could serve as a supplementary source of income for farmers especially in the dry season and a way of adjusting to climate change. However, major environmental factors such as recurrent droughts, hailstorms, floods, and pest/disease incidence influence livestock production. Also, poor nutrition and veterinary care, occurrence of diseases, unimproved animal breeds, inadequate budget allocation, limited infrastructure, and limited research on livestock (Befekadu and Berhanu 2000; Deressa *et al.*, 2008) contribute to poor livestock production. There is therefore the need for smallholder farmers to adapt good strategies and proper systems of rearing livestock in order to mitigate the harsh environmental conditions posed by climate change and also improve their system of livestock production and these, will help sustain their way of live.

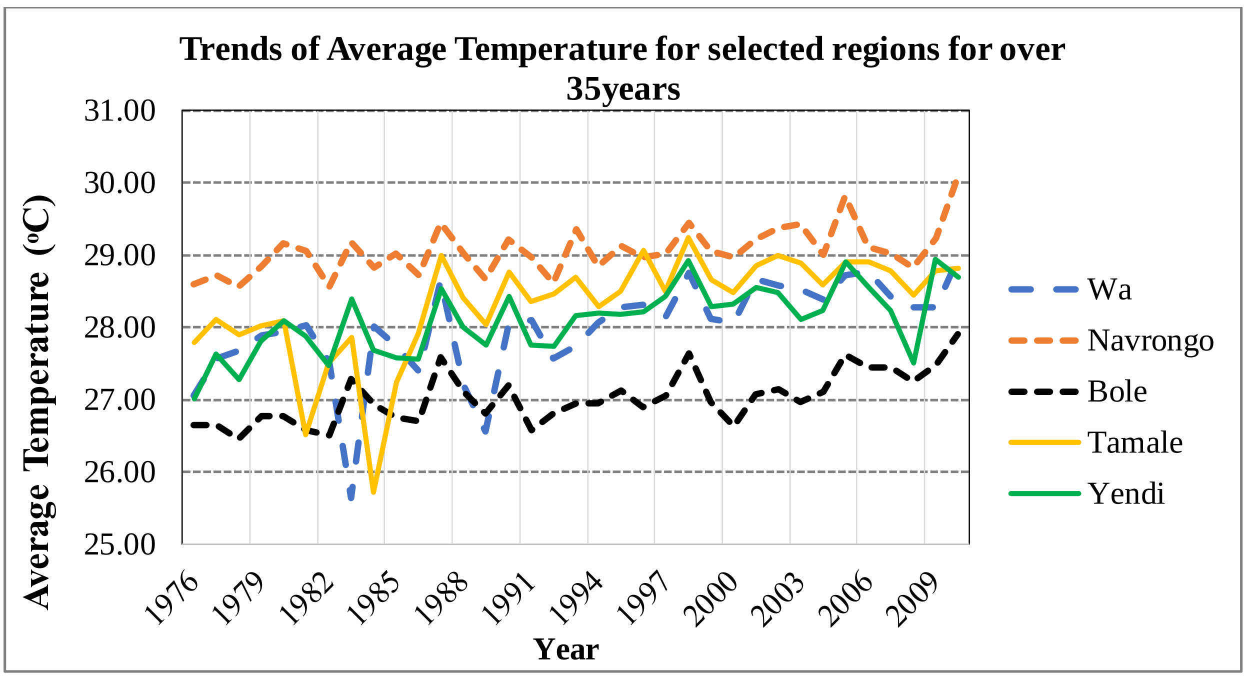
4.1.13 Temperature and Rainfall trends for some selected locations in Northern Ghana

This section presents and discusses the trends of important climate variables; temperature and rainfall, among some selected locations in Northern Ghana namely, Wa, Navrongo, Bole, Tamale and Yendi, for the past 35years (i.e. 1976 to 2011). Climate change is a long-term problem that has been unfolding over many decades. It is likely to lead not only to changes in the mean levels of temperatures and rainfall, but also to a significant increase in the variability of climate and in the frequency of extreme events (Skoufias *et al.*, 2011).

4.1.13.1 Trend of Temperature

The figure 4.8 shows that there is fluctuation in the trends of temperature among the selected locations namely, Wa, Navrongo, Bole, Tamale and Yendi, for over 35years (from 1976 to 2011). The altitude of a geographical location contributes to the extent to which temperature rises or falls. There has been gradual increase in temperature for the past 35years and there is still the potential for temperature to rise as projected global temperature will increase over the next few decades. This means that higher temperatures will be witnessed and this will have greater impacts on human, livestock and plants, and the environment making it a harsh place to live (Zoellick, 2009). IPCC fifth assessment report indicates that, impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (IPCC, 2014). The report added that, impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. These impacts are consistent with a significant lack of preparedness to current climate variability for countries at all levels of development (IPCC, 2014).

Figure 4.8: Trends of Average Temperature for selected regions for over 35years

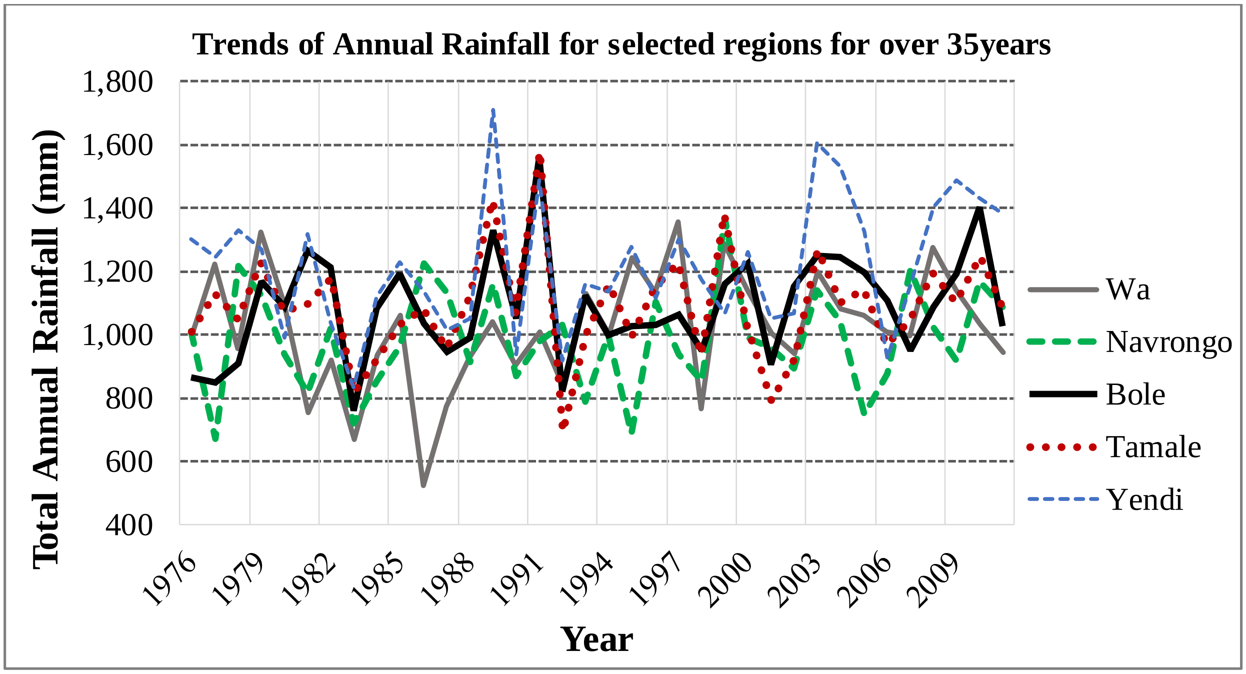


Source: Own plot from CECAR data

4.1.13.2 Trend of Rainfall

Variability in the level and distribution of rainfall is the most important determinant of crop yields in smallholder, resource-poor farming systems in arid and semi-arid areas, where farmers often lack sufficient yield improving inputs or technology (Amikuzuno and Donkoh, 2012). The figure 4.9 shows an undulating pattern of rainfall among some selected locations in Northern Ghana namely, Wa, Navrongo, Bole, Tamale and Yendi, for over 35years (1976 to 2011).

Figure 4.9: Trends of Annual Rainfall for selected regions for over 35years



Source: Own plot from CECAR data

There have been variations in the trend of rainfall for these selected locations showing a greater rise from 1988 to 1992 for Tamale and Yendi and a greater rise from 2002 to 2005 for Yendi. The rainfall levels alternate between peaks and troughs around the mean rainfall level of about 1,100mm. The seasonal variability in the rainfall pattern is quite clear within a range of 500mm and 1700mm. These represent periods of droughts and floods, hence risk for crop yields. The rise and fall in total annual rainfall for these selected locations may have greater impacts on human livelihoods, plants, livestock and the environment through incidence such as flooding, pest and disease outbreaks for both crops and livestock, destruction of farm lands through land degradation particularly, soil erosion, destruction of properties and loss of livelihood. The figure 4.9 shows gradual fluctuation in total annual rainfall for the past 35years but as shown, there is the potential fall for total annual rainfall from 2011 for all the selected locations. Vulnerability issue has the tendency to increase among these locations if people do not adapt and learn to live with the changing climate; most of the people will be affected.

4.1.14 Modelling Climate-Perturbed Crop and Livestock Yields for TOA-MD

The TOA-MD model is designed to simulate and compare two systems; a base system and a system that is operated under altered conditions such that it provides different economic outcomes for farms. For climate change impact assessment, farmers are considered initially to be operating a base technology with a base climate, in specified socio-economic conditions. The TOA-MD model simulates the economic, environmental and social outcomes associated with each system to quantify the impacts of climate change. Impacts that can be simulated using the TOA-MD model include changes in farm income or poverty rates, as well as other environmental or social outcomes of interest such as changes in greenhouse gas emissions or human health (Antle, 2011).

The TOA-MD model was used to analyse a total of 200 farm households sampled from the catchment area of the SKB. In the TOA-MD model, each production activity (an individual crop species or livestock) generates an output that can be measured on a per-farm basis (e.g., kg/farm/time). In this discussion, outputs of multiple crop farms were considered in a single season (maize cowpea and groundnut) and crop yields defined as kg/farm/season. The data used for the analysis included variables like farm size, household size, herd size, off-farm income, land use and farm management activities obtained from these farms (maize, cowpea and groundnut) and livestock enterprises. Also, the TOA-MD carries out simulations for a population of farms in specified strata, and in this discussion; two strata defined as cereal-based system which will be considered as sub-system 1 and legume-based system which will be considered as sub-system 2.

The production of a farm was represented in terms of the mean output of the farms in each stratum, and a variance of output among the farms in the stratum, using the TOA-MD. Variations were observed across farms as a result of physical, biological, economic and social factors (Antle, 2011).

Table 4.9 present a summary of the key variables used to estimate the TOA-MD model parameters.

Table. 4.9: Preliminary results table

	Cereal-based System			Legume-based System		
Parameter/Strata	Mean	Std. Dev.	CV (%)	Mean	Std. Dev.	CV (%)
Farm Characteristic						
Household size	14.47	7.34	50.72	12.43	7.70	61.98
Farm size	4.93	3.58	72.54	4.81	4.35	90.32
Herd size	37.17	40.48	108.90	42.92	43.22	100.71
Off-Farm Income	3157.47	4335.46	137.31	4150.77	4398.22	105.96
Maize						
Yield/farm (kg)	1093.19	1522.59	139.28	998.63	1214.19	121.59
Var. Cost/farm (GH¢)	1475.41	1193.15	80.87	2034.68	3677.57	180.74
Net Rev./farm (GH¢)	-193.95	911.61	-470.02	-609.68	1481.78	-243.04
Price (GH¢/kg)	0.42	0.03	6.17	0.44	0.04	10.16
Cowpea						
Yield/farm (kg)	605.62	850.00	140.35	1854.03	2043.80	110.24
Var. Cost/farm (GH¢)	778.60	757.53	97.29	1613.14	1396.18	86.55
Net Rev./farm (GH¢)	1282.93	1595.65	124.38	3293.29	3935.86	119.51
Price (GH¢/kg)	2.00	0.16	8.13	2.06	0.16	7.97
Groundnut						
Yield/farm (kg)	548.77	481.73	87.78	370.65	58.24	15.71

Var. Cost/farm (GH¢)	163.81	89.03	54.35	154.00	217.79	141.42
Net Rev./farm (GH¢)	231.19	537.61	232.54	76.00	316.78	416.82
Price (GH¢/kg)	0.54	0.13	24.23	0.50	0.14	28.28
Livestock						
Var. Cost (GH¢)	514.91	676.73	131.43	772.38	1192.50	154.39
Net Rev./farm (GH¢)	727.68	2159.68	296.79	973.63	3514.18	360.94

Two sub-systems are considered in the geographic region, namely; cereal-based and legume-based systems.

4.1.15 Climate Change Projections

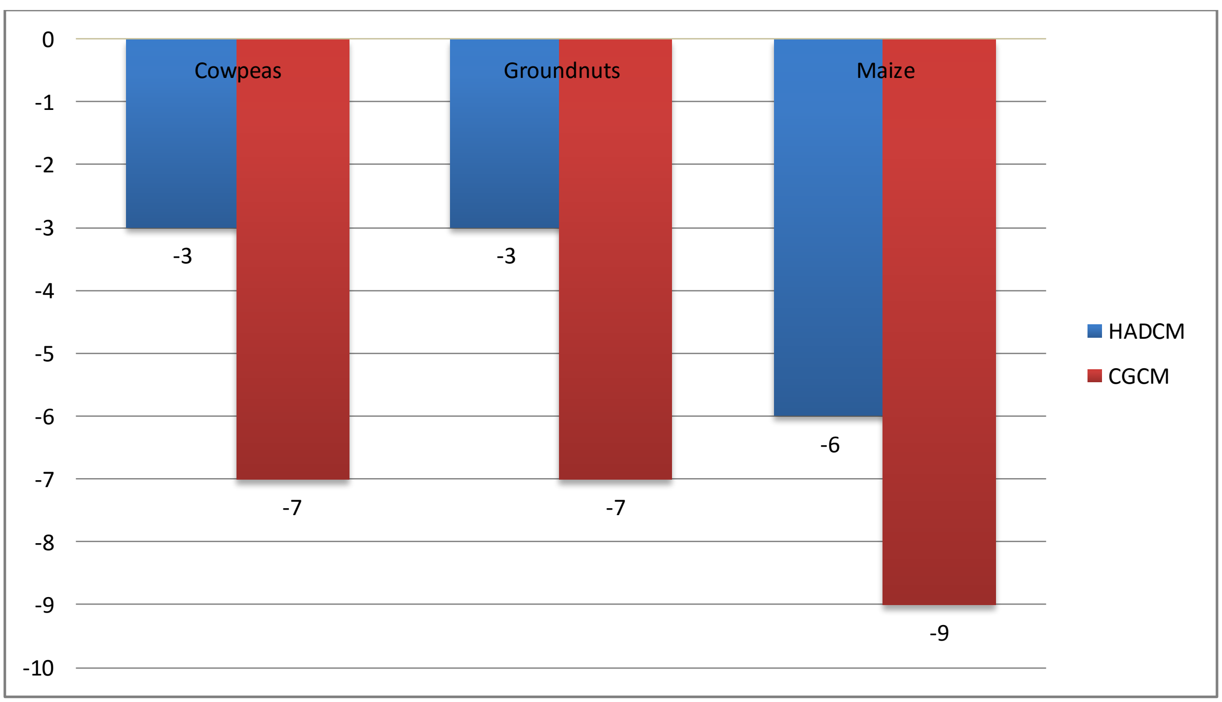
For the purpose of our study to analyse climate change impacts on crop yields, two scenarios were explored – Hadley Centre Coupled Climate Model (HADCM) and Canadian Global Coupled Climate Model (CGCM) projections for 2030; these models were used to simulate changes in production thus, assessing climate change implications on peoples' livelihood (yields, income, food security and poverty levels) by 2030 using biophysical simulation models (Butt *et al.*, 2003). Both the HADCM and CGCM projected decrease in yields for maize, groundnuts and cowpeas.

The adverse impact of climate change on yields would lessen food production and consumption; worsen food security conditions *ceteris paribus* (Downing, 1992; Butt *et al.*, 2003). However, reports indicate that, societies may adapt to climate change by altering production practices, developing new technologies, changing regional cropping patterns, altering consumption patterns, or increasing imports (Adams *et al.*, 1998b; Butt *et al.*, 2003).

The intensive and expanded (I &E) model, based on the assumption that irrigation water from the SKB will be used as an adaptation strategy to bring yields levels up to 95% of their baseline values, was tested as an adaptation strategy under a third scenario adapted from Amikuzuno and Hathie (2013). We tested recommended 16% and 25% reduction in yields of livestock for HADCM and CGCM respectively caused by declines in feed intake and availability.

Rain-fed yield changes are driven both by temperature and precipitation (Amikuzuno and Donkoh, 2012). The erratic nature of these climate variables affects yields especially in drier areas of the world (Dyszynski, 2010) of which the NR of Ghana is no exception. The projected rise in temperature and reduction in precipitation will have adverse effects on staples and therefore, adaptation of improved strategies becomes crucial. Adaptation considerations including increased irrigation in the SKB (with assumed sustainable water use) and improved land management will increase yields, reduce overall production and welfare losses, and alleviate child malnutrition. This will in turn ensure food security in the SKB and reduce poverty levels among smallholder farmers.

Fig. 4.10: Nationally Area Weighted Impacts under the Projected Climate



HADCM: Hadley Coupled Model; CGCM: Canadian Coupled Model.

Source: Plot from Butt *et al.* (2003) projections

4.1.16 Climate simulation results for the SKB

4.1.16.1 Climate Change Impact on Gains, Losses and Adoption rates (%)

It is expected that changes in climatic conditions will affect the economic outcomes of the system 1 causing some farmers to adopt system 2 where they will employ improved technology. Farmers are economically rational people and will only adopt new strategies when they realize that, the opportunity cost of moving from system 1 to system 2 is less than zero. Thus, farmers as rational as they are will adopt when the net revenue obtained from system 2 is greater than that obtained from system 1.

Table 4.10 presents the adoption rates, gains and losses and net gains under the different scenarios for the two sub-systems (Cereal-based farms and Legume-based farms) and for the entire populations of farms. It highlights the gains and losses for using a base system under climate change (system 1) and also presents the potential gains and losses for adopting the new strategy (system 2).

Table 4.10: Climate Impact on Gains, Losses and Adoption rates

Scenario/Stratum	Adoption rate (%)	Gains (%)	Losses (%)	Net Gains (%)
HADCM				
Cereal-based farms	56.81	29.43	19.14	10.29
Legume-based farms	58.14	34.83	20.81	14.03
All farms	56.91	12.01	7.72	4.28
CGCM				
Cereal-based farms	57.01	27.69	17.78	9.92
Legume-based farms	57.84	31.83	19.38	12.45
All farms	57.07	11.38	7.26	4.12

I & E				
Cereal-based farms	77.90	79.87	11.32	68.55
Legume-based farms	78.91	100.96	13.07	87.89
All farms	77.97	31.55	4.41	27.14

Gains, losses and net impact are expressed as a percentage of mean net household income

The results indicate that, under the changing climate, leguminous farms will thrive well than cereal farms. This is because; yields of leguminous crops will be better off under increased temperature and reduced rainfall than its cereal counterpart. The results revealed that, farm incomes were sensitive to climate change with or without adaptation. The income gains of farmers have the potential to increase as farmers adopt the new technology. The results showed higher income gains for farms that have adopted the new technology for the entire population of farms; 31.55% under the I&E scenario as against the entire population of farms without adaptation; 12.01% and 11.38% under HADCM and CGCM scenarios respectively. Accompanying these gains are decreased loss percentage for farms that have switched from system 1 to system 2; 4.41% under the I&E scenario as against the farms within system 1; 7.72% and 7.26% under HADCM and CGCM scenarios respectively. The aggregated net gains for the entire farms were 4.28%, 4.12% and 27.14% under HADCM, CGCM and I&E scenarios respectively. This clearly indicates that adoption of irrigation strategy will increase net gains from 4.12% under CGCM to 27.14% under I&E scenarios. Thus, adaptation to irrigation strategy will help reduce the adverse effects of climate change which results in erratic rainfall and temperature on farm productivity and therefore income.

The results on the adoption rates show that, farms with access to irrigation had higher adoption rates than farms without irrigation access. The adoption rates for the entire population of farms were 56.81%, 57.07% and 77.97% for the HADCM, CGCM and I&E

scenarios respectively. These percentages represent gainers (percentage of farmers who gain) under climate change. This therefore implies that, as the climate changes, access to irrigation will have the potential to increase the adoption rate of farmers indicating a greater percentage of gainers under climate change.

4.1.16.2 Climate Change Impact on Poverty rates (%)

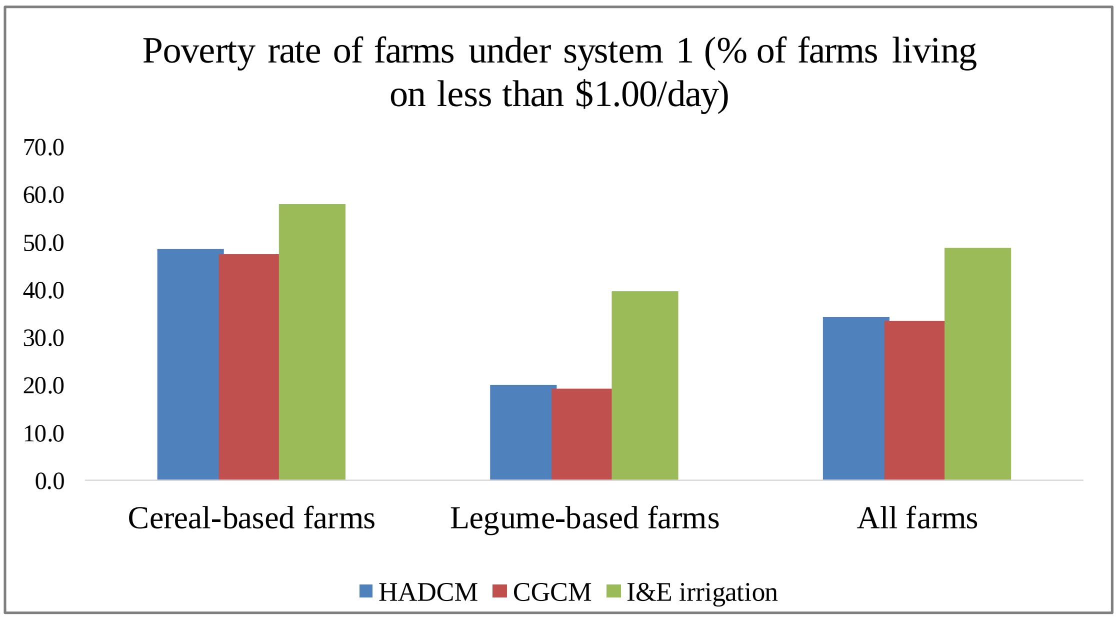
It is estimated that, about one billion people worldwide live on less than US$1 a day and that, about 2.6 billion (40% of the world's population) live less than US$2 a day. In Sub-Saharan Africa, 41% live on less than US$1 a day (Knoll and Hadden, 2012).

For the purpose of this analysis, we estimated poverty rates (percentage of the farm population living on less than $1.00/day) due to climate change under the three scenarios at the disaggregated and aggregated levels (See figures 4.11 and 4.12).

Climate change is detrimental to the poor because it will increase their vulnerability and reduce their resilience. Climate change will have negative impact on farm productivity for countries across Sub Saharan (Maddison, 2006). Studies have indicated that, climate change will slow down the progress on poverty reduction in the developing countries; this is because, most developing countries are more dependent on agriculture and climate-sensitive natural resources for income and welfare and that developing countries also lack financial and technical capacities to manage increasing climate risk (Skoufias *et al.*, 2011).

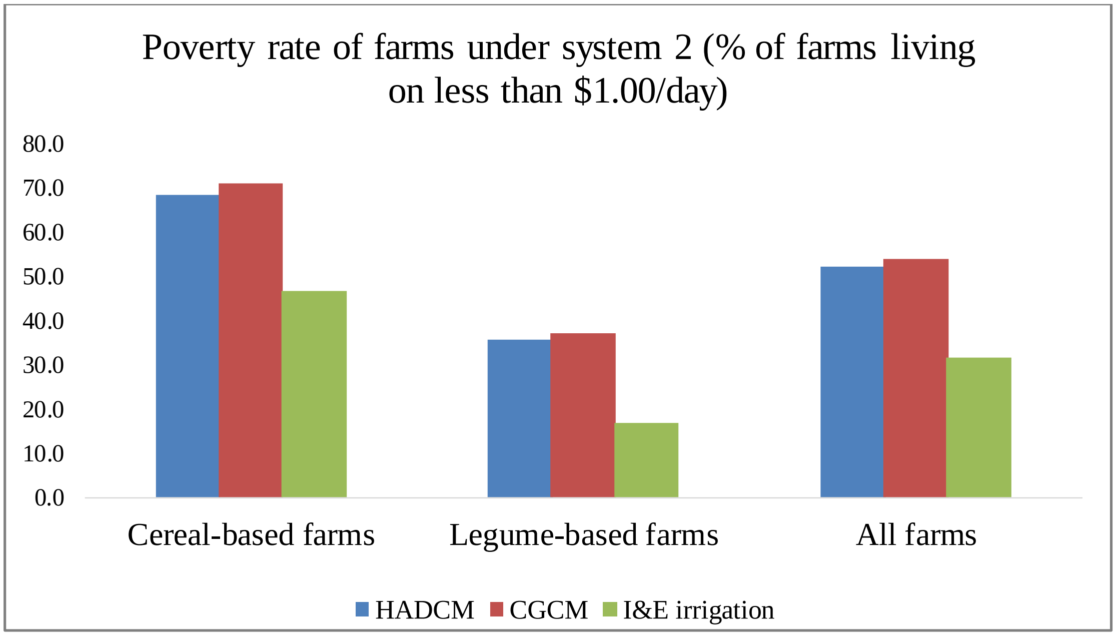
Ghana, for instance, is projected to suffer loss or decline in farm produce by 13.8% without technology adaptation (Maddison, 2006). This indicates that, yields of staples have the potential to decrease under climate change and in that case, nutritious food needed to meet the dietary requirements and food preferences of people for an active and healthy life will not be achieved. Food insecurity and malnourished among children have the tendency to increase. Poverty incidence will rise and will be more pronounced particularly in the Northern part of Ghana where vulnerability is overwhelming. Figures 4.11 and 4.12 show the poverty rate of farms under systems 1 and 2 respectively; farmers living on less than $1.00 a day.

Figure 4.11: Poverty rate (%) under System 1



Population, System 1and System 2 Poverty rates are expressed in percentages (%)

Fig. 4.12: Poverty rate (%) under System 2



Population, System 1and System 2 Poverty rates are expressed in percentages (%)

Source: Own Plots

The results of the estimated poverty rate shows that farmers will become poorer if they choose to remain in the use of system 1 (base technology), under climate change. This may be as result of decreased yields, increased cost of production due to vulnerability and decreased per-capita income. The result in figure 4.11 indicates that, poverty rate has the potential to rise to 48.8% for the entire population. This clearly indicates that climate change will have adverse effect on peoples' livelihood thereby increasing the incidence of poverty.

The results in figure 4.12 indicate that adaptation to irrigation strategy will have impact on poverty rate. Under the system 2 where farmers decide to switch from the use of base technology and adapt to improved technology, has the potential to decrease poverty rate to 31.6% for the entire population. This will be as a result of increased farm productivity;

increased yields translating into increased per-capita income of farms and this will help improve the livelihoods of the people. It is plausible that the peoples' livelihoods will improve because; adaptation to climate change is a priority for ensuring long-term effectiveness of investing in poverty eradication and sustainable development.

4.1.16.3 Climate Change Impact on Mean Net Revenue per farm

In Ghana, agricultural production is largely smallholder and rain-fed (GEPA 2007); and due to that, any slight change in weather and climate will pose major challenges to the growth and development of the agriculture sector (Nankani 2009). The drier nature of the Northern part of Ghana and its dependency on rain-fed agriculture exposes the region to the direct impacts of increase temperature and decrease precipitation. The implications may include inadequate rains for cropping; destruction of crops; stretched drought; decrease yields and incidence of pests and diseases. This will in turn impede the realisation of food security and also increase poverty levels in the Northern Ghana if smallholder farmers do not adapt. Studies have indicated decline in farm productivity (Dyszynski, 2010) which will have adverse effect on mean net returns. Table 4.11 shows the mean net revenues impacts of climate change in the SKB;

Table 4.11: Climate Impact on Mean net revenues per farm

Scenario/Stratum	Mean-net revenue for System 1	Mean-net revenue for System 2	% Change
HADCM			
Cereal-based farms	793.45	1,563.01	0.97
Legume-based farms	4,081.35	3,379.00	-0.17
All farms	1039.60	1698.97	0.63
CGCM			
Cereal-based farms	907.67	1389.80	0.53
Legume-based farms	4076.55	3059.13	-0.25
All farms	1144.91	1514.78	0.32

I & E			
Cereal-based farms	-232.52	3551.81	14.28
Legume-based farms	298.54	9216.56	29.87
All farms	-192.76	3975.91	19.63

Mean Net Revenues are expressed in Ghana Cedi per farm at a given time

Results from our study show a decrease in mean net revenues from 1,039.60 under HADCM to -192.76 under I&E, for the entire population (See table 4.11) if farmers do not adapt the improved technology. The importance of the agricultural sector particularly to the Ghanaian economy cannot be overemphasized. Climate change will have negative impact on agricultural production and revenues of staples. Studies have indicated that, climate change will have adverse impact on net revenue per farm and production widely across African agro-ecological systems particularly with dry land farms that are being sensitive to temperature increases and precipitation reduction (Dyszynski, 2010). Adaptation to improved strategy; to adjust to the adverse effects of climate change therefore becomes crucial for the country.

Results from the study indicates that, farmers that switch from system 1 to adapt the new strategy have the potential to increase their mean net revenues from 1698.97 under HADCM to 3975.91 under I&E (See table 4.11). This therefore indicates that, as climate change is exacerbating there is the urgency for smallholder farmers in the SKB to adapt strategies such as irrigation technology; to help reduce climate change risks which could result through crop or livestock yield losses. Also, the percentage change between mean net returns under system 1 and system 2 for the three different scenarios – HADCM, CGCM and I&E confirms that, the use of the intended and extended system of irrigation will help reduce the adverse impacts of climate change on mean net revenues.

4.1.16.4 Climate Change Impact on Per Capita Income of farms

The distributional climate impacts from reduced agricultural productivity will result in employment losses (largely unskilled labour), causing expansion in other sectors while also pushing down wages. The poorest household group in the agriculture sector which includes subsistence farmers will be the most negatively affected from climate change with an estimated 12.2% reduction in income. Climate change impacts on the agricultural sector are estimated to have macroeconomic impacts of 1.1% up to 3.5% on Gross Domestic Products, with highly uneven distributional impacts on unskilled rural labour and households (Dyszynski, 2010). The agricultural sector for developing countries faces greater risk to climate change because it is a climate-sensitive sector and also as a result of the limited human, institutional, and financial capacity to anticipate and respond to the direct and indirect effects of climate change. Adaption to improved strategies therefore becomes crucial for these sub-regions. Table 4.12 shows the climate impact on per capita income for farms in the SKB, with and without adaptation.

Table 4.12: Climate Impact on Per Capita Income for farms

Scenario/Stratum	Per capita income for system 1	Per capita income for system 2	% Change
HADCM			
Cereal-based farms	343.32	221.41	-0.36
Legume-based farms	916.80	488.60	-0.47
All farms	630.06	355.01	-0.44
CGCM			
Cereal-based farms	353.24	209.90	-0.41
Legume-based farms	916.27	461.20	-0.50
All farms	634.75	335.55	-0.47

I & E			
Cereal-based farms	254.16	353.60	0.39
Legume-based farms	495.52	988.70	1.00
All farms	374.84	671.15	0.79

Per capita incomes for farms are expressed in Ghana Cedi per person at a given time.

The results from our study reveal that, the per capita income for farms has the potential to decrease to 374.84 (See table 4.12) if farmers decide to continuously use their base system of production under the changed climate. Climate change will affect the per capita income of farms through factors such as high cost of production, crop failure/losses, decreased crops/livestock yields and decreased net revenues. Studies have already indicated that developing countries (of which Ghana is no exception and therefore the SKB) are expected to suffer the most from the negative impacts of climate change, without adaptation. The need therefore to adapt improved technologies becomes crucial to smallholder farmers.

The per capita income for farm has the potential to increase to 671.15 for all farms (See table 4.12) if farmers switch from system 1 to adapt the new technology; system 2. This will be realised through improved yields. This is because, the establishment of irrigation or supplementary systems has the potential to support dry season farming in the SKB; and that will help to reduce smallholder farmers' dependency on rainfall as well as enhance livelihood through additional agricultural production outside of the rainy season. Moreover, the percentage change between the per capita income under system 1 and system 2 for the three different scenarios – HADCM, CGCM and I&E confirms that, the use of the intended and extended system of irrigation will help reduce the adverse impacts of climate change by improving peoples' livelihoods.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.2 Summary and Conclusion

The results of our study showed that, agriculture in the SKB is predominantly rain-fed where smallholder farmers are exposed to the erratic nature of the climate variables and the consequences that follows. A wide range of rain-fed crops including maize, cowpea, rice, millet, groundnut and a variety of vegetables are cultivated; among which maize and cowpea are predominantly cropped. Majority (90%) of crop farmers in the SKB owned livestock where rearing of these livestock was generally extensive and not integrated into the cropping system as would be done in mixed farming. The major livestock types raised were cattle, goat, sheep and poultry (chicken and guinea fowls).

The system of crop farming in the SKB is commonly bush fallow involving intercropping among natural economic trees like Shea (*Vitellaria paradoxa*) and Dawadawa (*Parkia biglobosa*) on a rotational basis. It comprises of lowland bush fallow farms (flood lands) and upland bush fallow farms. Uplands are cultivated during the peak of the raining season. Seasonal flooding of lowlands by the Sisili-Kulpawn River allows the lowlands to be cropped twice; before and after the floods. This allows smallholder farmers to cultivate twice within a cropping season (Early- and late- cropping season). The floods also leave behind relatively more fertile soil which offers farmers the opportunity of increasing their yields.

Despite these advantages, smallholder farmers are faced with the challenges posed by the erratic nature of rainfall and unpredictable flooding of farms at the lowlands by the Sisili-Kulpawn River. Farmers who farm the uplands are faced with long period of drought during the dry season. Also, smallholder farmers within the study area were encountered with production challenges such as pest and disease attacks.

The consequences thereafter include total crop/livestock losses, decrease in crop/livestock yields, destruction of farm lands, and loss of soil fertility (degradation). Climate change will increase the vulnerability of these smallholders by worsening their challenges and this will elevate poverty levels. Adaptation of strategies in order to adjust to climate change has become a more critical issue in the survival of smallholder farmers.

In using the Cobb-Douglas production function approach to test the significant effects of production inputs on output levels; our study revealed that, smallholder farmers in the SKB were producing in the first stage of the production function having a return to scale value of 0.82. This implies that, as total input usage increases, output increases more than proportionate increase in the inputs used; clearly showing that smallholders have the potential to increase their input usage needed for an acre of farm land. Smallholder farmers therefore need to scale-up their usage per an acre of land in order to reap the maximum gains from these inputs used.

In assessing the trends of temperature and rainfall, there was an undulating pattern among some selected locations (Wa, Navrongo, Bole, Tamale and Yendi) in Northern Ghana for over 35years. There have been fluctuations in the trends of temperature and rainfall showing variability in yields of major staples of the Northern Ghana. The erratic nature of rainfall and temperature which may result in floods or droughts will have adverse effect on yields of major staples. The incidences may include total loss of crops, decreased yields, bush fires and more confirming reports from previous studies (Amikuzuno and Hathie, 2013) that, yields of staples; maize and cowpea , millet, sorghum, rice, yam and groundnuts in the Northern part of Ghana of which the SKB is no exception, has the tendency to decline. As the climate is always changing, annual rainfall will decrease whereas average temperature will increase particularly in Northern Ghana and this will have adverse implication on yields. This implies that without adaptation, yields of staples in the SKB will decline thereby increasing food insecurity and worsening poverty rate in Northern Ghana.

Results from the TOA-MD analysis also indicated that, climate change will have adverse impact on gains and losses, poverty rates, mean net revenues per farm and per capita income of farmers in the SKB if farmers do not adapt to climate change. The results revealed a decreased mean net gain of 4.20%; net revenue of -192.76 and per capita income of 374.84 for farms that do not adapt but an increased net gain of 27.14%; net revenue of 3,975.91 and per capita income of 671.15 for farms that adapt, also increase in poverty rate of about 48.8% for farms that do not adapt but decrease in poverty rate of about 31.6% for farms that adapt. Adaptation to improved strategies such as irrigation strategy which will serve as a supplementary source of water to dry season farming in the SKB will help to reduce smallholder farmers' dependency on rainfall as well as enhance livelihood through additional agricultural production outside of the rainy season. This will help counteract the adverse impacts of climate change on income gains, mean net revenues, per capita income and poverty rates.

The consequences of climate change on agricultural production will be pronounced if smallholder farmers in the SKB continuously use their base system of production under the changed climate. The study found out that, livelihood outcome variables like income and poverty levels are sensitive to the different climate scenarios. Climate change will reduce yields, income, mean net revenue and resilience of farmers in the study area but good adaptation strategies (good agronomic practices and irrigation strategies) will be required to offset such effects. The use of adaptation to climate change as an entry point is therefore crucial for the improvement of farmers' resilience and disaster preparedness and also for the sustainability of the agriculture sector in the SKB, Northern Ghana and the country as a whole.

5.3 Recommendations

- The presence of the Sisili-Kulpawn River offers a potential for the establishment of irrigation/supplementary systems to support dry season farming in the SKB especially, (an ongoing irrigation project initiation by IWAD and SADA); this will help to alleviate farmers' dependency on rainfall as well as enhance livelihood through additional agricultural production outside of the rainy season. Also provision of infrastructure such as water storage/harvesters and storm shelters become necessities.
- Due to the high variability and seasonality of the rainfall events, access to information on the climate, inputs and technological services becomes very crucial. MOFA and other stakeholders like Wienco should be able to assist farmers to know correct timing for planting (access to weather information services) to prevent/reduce loss of crop through flooding and/or delay in rains. In this regard, smallholder farmers will be able to build their resilience. Stakeholders should provide financial services and weather-related insurance to support farmers in this regard.
- Smallholder farmers have the potential to increase their farm size since there are ample lands available for cultivation. The study therefore recommends that farmers should increase their farm lands under cultivation and with the adaptation of improved technologies; this will translate into higher yields and incomes thereby improving the peoples' livelihood.
- Research institutions like CSIR/SARI, NGO's and other stakeholders in agriculture should be able to provide and encourage smallholders to adopt new crop varieties (that have attributes like heat tolerance; early maturing; drought tolerance; high resistance to pests and

diseases; high yield and responsiveness to day length), including adoption of livestock species (that are better suited to drier conditions), irrigation technology, and conservation agriculture and sustainable land management such as crop diversification; adoption of mixed farming systems; crop rotation and changing planting dates. This will help build the resilience of farmers to climate change.

- Farmers` acceptance and willingness to adopt or invest in certain strategies/technologies that will increase agricultural production is an issue worth tackling. Agricultural extension service within MOFA and other stakeholders who are into the development of agriculture should assist in the sensitization process of farmers. The study recommends that, smallholder should be engaged in the adaptation strategy process and this will help ensure the use and sustainability of the technology.
- The GoG and other development agencies who are interested in agricultural development should support in the construction of roads that connect Yagaba to other major food-producing areas including Soo, kpatorigu and Yizesi. This is because during rainy season, a number of settlements in the district are cut off especially the area christened "Second Overseas"; this will boost production.

REFERENCES

Adams, A. M., Cekan, J. and Sauerborn, R. (1998a). Towards a conceptual framework of household coping: Reflections from Rural West Africa, Africa. *Journal of the International African Institute*, 68:263–283.

Adams, R. M. (1989). Global climate change and agriculture: An economic perspective. *American Journal of Agricultural Economics*, 71 (5): 1272–79.

Adams, R.M., McCarl, B.A., Segerson, K., Rosenzweig, C., Bryant, K.J., Dixon, B.L., Conner, R., Evenson, R.E. and Ojima. D. (1998b). The economic effects of climate change on U.S. agriculture. In Mendelsohn R. and Neumann J. (eds.) *The Economics of Climate Change*, Cambridge University Press, Cambridge, pp. 18-54.

Alexandrov, V. A. and Hoogenboom, G. (2000). The impact of climate variability and change on crop yield in Bulgaria. *Agriculture and Forest Meteorology*, 104: 315–27.

America's Climate Choices: Panel on Advancing the Science of Climate Change; National Research Council (2010). *Advancing the Science of Climate Change*. Washington, D.C.: The National Academies Press, p. 1.

Amikuzuno, J. (2013). Climate change impact on smallholder farmers in the White Volta Basin of the Upper East Region of Ghana. Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, Hammamet, Tunisia.

Amikuzuno, J. and Donkoh, S. A. (2012). Climate variability and yields of major staple food crops in Northern Ghana. *African Crop Science Journal*, Vol. 20, Issue Supplement s2, pp. 349 – 360. © African Crop Science Society. ISSN 1021-9730/2012.

Amikuzuno, J. and Hathie, I. (2013). Climate change implications for smallholder agriculture and adaptation in the White Volta Basin of the Upper East Region of Ghana. Impacts World 2013, International Conference on Climate Change Effects, Potsdam, May 27-30.

Anane-Sakyi, C., Abunyewa, A. A., Nyamekye, A. I. and Safo, E. Y. (2013). Ghana Agricultural Information Network System. [Online] Available at: http://www.gains.org.gh/documents [Accessed 19 January 2015].

Angelucci, F., Asante-Poku, A. and Anaadumba, P. (2013). *Analysis of incentives and disincentives for rice in Ghana*. Technical notes series, MAFAP, FAO, Rome.

Antle, J. (2011). Parsimonious multi-dimensional impact assessment. *American journal of Agricultural Economics*, 93(5), 1292-1311.

Antle, J.M. and Valdivia, R.O. (2006). Modeling the supply of ecosystem services from agriculture: A minimum-data approach. *Australian Journal of Agricultural and Resource Economics*, 50: pp1-15. © Australian Agricultural and Resource Economics Society Inc. and Blackwell Publishing Ltd.

Antle, J.M. and Valdivia, R.O. (2011). *Methods for assessing economic, environmental and social impacts of aquaculture technologies. Adoption of Integrated Agriculture-Aquaculture in Malawi*. Unpublished.

Apata, T.G., Ogunyinka, A.I., Sanusi, R.A. and Ogunwande, S. (2010). Effect of global climate change on Nigerian Agriculture. An empirical analysis. The 84th Annual Conference of the Agricultural Economics society, Edinburg- Scotland on 29-31 March.

Apata, T.G., Samuel, K.D. and Adeola, A.O. (2009). Analysis of climate change perception and adaptation among arable food crop farmers in South Western Nigeria. Contributed Paper prepared for presentation at the International Association of Agricultural Economists' 2009 Conference, Beijing, China, August 16-22, 209.

Armah, F.A., Odoio, J.O., Yengoh, G.T., Obiri, S., Yawson, D.O., and Afrifa, E.K.A. (2010). Food security and climate change in drought-sensitive savanna zones of Ghana. *Mitigation and Adaptation Strategies for Global Change*, 16(3), 291-306. Available at: www.bbc.com.uk.

Assan, J. K., Caminade, C. and Obeng, F. (2009). 'Environmental variability and vulnerable livelihoods: minimizing risks and optimizing opportunities for poverty alleviation'. *Journal of International Development*. 21: 403-418.

Baumgartner, A.J.G., Jockel, P., Dameris, M. and Crutzen, P.J. (2010). Will climate change increase ozone depletion from low-energy-electron precipitation? Atmospheric Chemistry and Physics. *Atmos.Chem.Phys.* 10, 9647-9656.

Befekadu, D. and Berhanu. N. (2000). *Annual report on the Ethiopian economy*, Vol.1. Ethiopian Economic Association. Addis Ababa, Ethiopia.

Blench, R.M. (1999). Agriculture and the environment in Northeastern Ghana: A comparison of high and medium Population density areas. In Blench R.M. (ed.) *Natural Resource*

Management and Socio-economic Factors in Ghana. 21-43. London: Overseas Development Institute.

BNRCC, (2008): 2008 Annual Workshop of Nigerian Environmental Study Team (NEST): The Recent Global and Local Action on Climate Change, held at Hotel Millennium, Abuja, Nigeria; 8-9th October, 2008.

Breisinger, C., Diao, X., and Thurlow, J. (2008). Agriculture for development in Ghana. IFPRI Discussion Paper 00784. Washington: International Food Policy Research Institute.

Brown, O. and Crawford, A. (2008). Assessing the security implications of climate change for West Africa-Country: Case studies of Ghana and Burkina Faso. Winnipeg: International Institute for Sustainable Development.

Bruinsma, J. (2009). The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050? Expert meeting on how to feed the world in 2050, Food and Agriculture Organization of the United Nations, Economic and Social Development Department.

Brussel, S.E.C. (2009). Adapting to climate changes: the challenge for European agriculture and rural areas. Commission of the European communities. Commission working staff working document accompanying the white paper No. 147.

Burroughs, W.J. (2001). *Climate change: A multidisciplinary approach*. 2nd edition, Pp 284-285, Cambridge University Press.

Butt, T. A., MaCarl, B. A., Angerer, J., Dyke, P. T., Struth, J. W. (2003). Food security implication of climate change in developing countries: Findings from a case study in Mali. Published PhD Dissertation, Department of Agricultural Economics, Texas A&M University, and College Station, TX.

Calzadilla, A., T. Zhu, T., Redhanz, K., Tol, R. S. J. and Ringler, C. (2009). Economy wide Impacts of Climate Change in Sub-Saharan Africa, IFPRI Discussion Paper No. 873. Washington, DC: International Food Policy Research Institute.

Cap-Net (2010). Integrated Water Resources Management as a Tool for Adaptation to Climate Change. [Online] Available at: http://www.cap-net.org/sites/cap-net.org/files/ [Accessed 12 June 2010].

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P., and Kassam, A. (2007). Assessing the vulnerability of food crop systems in Africa to climate change. *Climatic Change*, 83(3) 381-399.

Chang, C. (2002). The Potential Impact of Climate Change on Taiwan's Agriculture. *Agricultural Economics*, 27: 51–64.

Claessens, L., Antle, J.M., Stoorvogel, J.J., Valdivia, R., Thornton, P.K., Herrero, M. (2011). Assessing climate change adaptation strategies for small scale, semi-subsistence farming. Under revision for *Agricultural Systems*.

Cline, W. R. (1996). The Impact of Global Warming on Agriculture: Comment. *American Economic Review*, 86: 1309–12.

Cobb, C. W. and Douglas, P. H. (1928). A theory of production. *American Economic Review*, 18(1):139–165. Supplement Papers and Proceedings of the Fortieth Annual Meeting of the American Economic Association.

Datto, L. and Schiff, H. (1978). The ozone war. Doubleday & Co, Inc, Garden City, NY, Ch. 2, 3.

De Pinto, A., Demirag, U., Akiko, H., Koo, J. and Asamoah M. (2012). Climate Change, Agriculture, and Food crop Production in Ghana. Ghana Strategy Support Program (GSSP). International Food Policy Research Institute (IFPRI), Supported By CGIAR. Policy Note #3. September 2012.

Deressa, T., Hassan, R. M., Alemu, T., Yesuf, M. and Ringler, C. (2008). Analyzing the Determinants of farmers' choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. Environmental and Production Technology Division. IFPRI Discussion Paper 00798. International Food Policy Research Institute, Washington, D.C.

Deressa, T.T. and Hassan, R.M. (2009). Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures; *Journal of African economies*, Vol. 18, no.4, Pp 529-554 doi: 10, 1093/jae/ejpooe.

Dietz, T. *et al.* (2004). *Climate and Livelihood Change in North East Ghana, in the Impact of Climate Change on Dry lands with a Focus on West Africa*, edited by Dietz AJ, R. Ruben and A. Verhagen. Pages 149-172. Dordrecht. The Netherland: Kluwer Academic Publishers.

Dinar, A., Mendelsohn R., Evenson R., Parikh J., Sanghi A., Kumar K., McKinsey J. and Lonergan S. (1998). Measuring the Impact of Climate Change on Indian Agriculture, World Bank Technical Paper 402, Washington, DC.

Downing, T. (1992). Climate Change and Vulnerable Places: Global Food Security and Country Studies in Zimbabwe, Kenya, Senegal and Chile, Research Report No. 1, Environmental Change Unit, University of Oxford.

Du Toit, M. A., Prinsloo, S. and Marthinus, A. (2001). El Nin˜ o-southern oscillation effects on maize production in South Africa: A preliminary methodology study. In Rosenzweig, C., Boote, K. J., Hollinger, S., Iglesias A. and Phillips J. G. (eds) *Impacts of El Niňo and Climate Variability on Agriculture, ASA Special Publication 63*. Madison, WI, USA: American Society of Agronomy, pp. 77–86.

Dugje, I.Y., Omoigui, L.O., Ekeleme, F., Kamara, A.Y. and Ajeigbe, H. (2009). Farmers' Guide to Cowpea Production in West Africa. IITA, Ibadan, Nigeria. 20 pages.

Duncan, B. A. (2004). *Women in Agriculture in Ghana*. 2nd ed. Printright, Accra.

Dyszynski, J. (2010). UNEP AdaptCost briefing note: Economics of climate impacts and adaptation in Africa's agricultural sector. Stockholm Environment Institute (SEI), Oxford Office.

Ecologic Institute and SERI (2010). Establishing environmental sustainability thresholds and indicators. Final report to the European Commission's DG Environment, November 2010.

EEA (2000). Down to Earth: soil degradation and sustainable development in Europe. Environmental Issues Series Number 16. European Environment Agency, Copenhagen.

Enete, A. A. and Amusa, T. A. (2010). Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature. Field Actions Science Reports [Online], Vol. 4 | 2010, Online since 20 December 2010. URL: http://factsreports.revues.-org/678.

Enriquez, A. M. (2011). *Climate Change: The Need for a Gendered Perspective*. New York: UN Women

Euronet Consortium (2012). *Country Environmental Profile, Republic of Ghana*. European Union.

European Commission (2011). *Sustainable food consumption and production in a resource-constrained world. The 3rd SCAR Foresight Exercise*. Luxembourg: Publications Office of the European Union, Pp 7 & 25.

FAO (1996a). Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit, Rome; Pp 4.

FAO (1996b). Agro-ecological Zoning: Guidelines, FAO Soils Bulletin 73, Rome, Italy.

FAO (2001). *Soil Fertility Management in support of Food Security in sub-Saharan Africa*. Food and Agriculture Organization of the United Nations, Rome; Pp 1-50.

FAO (2003). Conceptual framework for national, agricultural, rural development, and food security strategies and policies, by K. Stamoulis and A. Zezza. Rome.

FAO (2008). *Climate Change and Food Security: A Framework Document*. Food and Agriculture Organization of the United Nations, Rome; Pp 1-71.

FAO/NRCB (2008). Poster presented at the International Conference on Food Security and Environmental Change, 2_4 April 2008. Oxford, UK.

Fischer, G., Shah, M., Tubiello, F.N. and van Velhuizen, H. (2005). Socio-economic and climate change impacts on agriculture: An integrated assessment, 1990-2080. Philosophical transactions of the Royal Society of London. Series B, Biological science, 360, 2067-2083.

Garfield, E. (1988). Ozone-layer depletion: Its consequences, the causal debate, and international cooperation. Essay of an information scientist. Science Literacy, Policy, Evaluation, and other essays, Vol.: 11, p.39. Current comments, #6, p.3-13.

GECAFS Online. About GECAFS. Available at: www.gecafs.org/glossary/index.html#-foodsystems.

GEPA (2007). Ghana's initial national communications report. United Nations Framework Convention on Climate Change, Accra.

Gillig, D. and McCarl, B.A. (2002). Introduction to Computable General Equilibrium Models (CGE). Department of Agricultural Economics, Texas A&M University, http://ageco.tamu.edu/

Gliessman, S.R. (1998). *Agro ecology: Ecological processes in sustainable agriculture*. Ann Arbor Press, Chelsea, MI.

GoG (2011). Ghana’s Second National Communication to the UNFCCC, 2011. Retrieved from http://unfccc.int.resource/docs/natc/ghana_second_nationalcommunication_final_ version.pdf. Accessed in April 3, 2012.

GSS (2002). *2000 population and housing census: summary report of final results*. Ghana Statistical Services, Accra

Hajkova, D. and Hurnik, J. (2007). Cobb-Douglas Production function: The Case of a converging economy. UDC:519.866;330.11;330.35http://meteoterm.wmo.nt/meteo-term/ns?

Hijmans, R. J. (2003). The effect of climate change on global potato production. *American journal of potato research*, 80(4), 271 -280

Humphrey, T.M. (1997). Algebraic Production Functions and their Uses before Cobb-Douglas. Federal Reserve Bank of Richmond Economic Quarterly, 83(1), pp. 51-83. Available at http://ideas.repec.org/a/fip/fedreq/y1997iwinp51-83.html.

Idso, C. D. (2011). Estimates of Global Food Production in the Year 2050: Will We Produce Enough to Adequately Feed the World? Center for the Study of Carbon Dioxide and Global Change.

IFAD (1998). Ghana: Improving women's access to Land in the Upper East. Available at http://www.ifad.org/gender/learning/resource/natural/40.htm. Accessed in August 3, 2014.

Igoden, C., Ohoji, P. and Ekpare, J. (1990). Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. *Agricultural Administration and Extension* 29 (2): 149–156.

ILO (2007). Chapter 4: Employment by sector. In Key indicators of the labour market (KILM), 5th edition. Available at: www.ilo.org/public/english/employment/strat/kilm/download/kilm04.pdf.

IPCC (2007). *Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. [Parry M.L., Canziani O.F., Palutikof J.P., van der Linden P.J. and Hanson C.E. (eds)]. Cambridge University Press: Cambridge, United Kingdom.

IPCC (2014). *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Jones, P. G. and Thornton, P. K. (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global Environmental Change*, 13 (1), 51-59.

Jones, P.G. and Thornton, P.K. (2002). Croppers to livestock keepers: Livelihood transition to 2010 in Africa due to climate change. Global Environmental Change, World Health Organization, Geneva, Switzerland.

Jones, R. J. A. (2002). Assessing the vulnerability of soils to degradation. Sustainable Land Management Environmental Protection. A soil physical approach. Advances in Geoecology 35.

Kaiser, H. M., Riha, S. J., Wilks, D. S., Rossiter D. G. and Sampath, R. K. (1993). A Farm-level Analysis of Economic and Agronomic Impacts of Gradual Warming, *American Journal of Agricultural Economics*, 75: 387–98.

Khanal, R.C. (2009). Climate change and organic agriculture. *The journal of agriculture and environment*, 10: 100-110.

Knoll, S. and Hadden, S., (2012). Where we stand as a Global family. Business Transformation Initiative.

Kolavalli, S., Robinson, E., Diao, X., Alpuerto, V., Folledo, R., Slavova, M., and Ngeleza, G. (2012). Economic transformation in Ghana: Where will the path lead? *IFPRI Discussion Paper 01161*. Washington: International Food Policy Research Institute.

Kropp, J. and Scholze, M. (2009). Climate change information for effective adaptation: A practitioner's manual; on behalf of Federal Ministry for Economic Cooperation and Development, POTSDAM Institute for climate Impact Research Esch-born.

Kumar, K. and Parikh, S. (1998). Climate change impacts on Indian Agriculture: the Ricardian approach, In: A. Dinar, R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K. Kumar, J. McKinsey, S. Lonergan (eds), Measuring the Impact of Climate Change on Indian Agriculture, World Bank Technical Paper No.402, Washington, DC: World Bank.

Lal, M. *et al.* (1999). Growth and Yield Responses of Soybean in Madhya Paradesh, India, to Climate Variability and Change, *Agriculture and Forest Meteorology*, 93 (1): 53–70.

Laube, W., Schraven, B. and Awo, M. (2011). Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Climate change*, 111, 753-774.

Lin, J. (1991). Education and innovation adoption in agriculture: Evidence from hybrid rice in China. *American Journal of Agricultural Economics* 73 (3): 713–723.

Mabe, F.N., Sarpong, D.B. and Osei-Asare, Y. (2012). Adaptive Capacities of farmers to Climate Change Adaptation Strategies and their effects on Rice Production in the Northern region of Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, No. 11 (11) / 2012.

Mabugu, R. (2002). The use of CGE modelling in the analysis of environmental policy reform. Collaborative Regional Masters in Environmental Economics and Policy (CEEPA) Specialization Course Module, Lecture notes, University of Pretoria, South Africa.

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

Mamprugu-Moaduri Distict Assembly (2013). District Profile of Mamprugu-Moaduri. Unpublished.

Marchetta, F. (2011). On the Move Livelihood Strategies in Northern Ghana. Centre D'etudes et de Recherches sur le Developpement Internation- Al. Cerdi, Etudes et Documents, E 2011.13.

Mariara, J.K. (2008). The economic impact of Global Warming on livestock husbandry in Kenya. A Ricardian analysis; Paper prepared for the African economic conference on globalization, Institutions Economic Development of Africa. Tunis.

McSweeney, C., New, M., Lizcano, G., and Lu, X. (2010). The UNDP climate change country profiles. *American Meteorological Society*, 91, 157-166.

Mendelsohn, R. and Tiwari D. (2000). Two Essays on Climate Change and Agriculture: A Developing Country Perspective. FAO Economic and Social Development Paper 145. Rome, Italy.

Mendelsohn, R., Nordhaus W. and Shaw D. (1994). The Impact of Global Warming on Agriculture: A Ricardian Analysis. *American Economic Review*, 84: 753–71.

Mishra, S.K. (2007). A Brief History of Production Functions Munich Personal RePEc Archive (MPRA). North-Eastern Hill University, Shillong (India). Online at http://mpra.ub.unimuenchen.de/5254/. MPRA Paper No. 5254, posted 10. October 2007.

Müller-Kuckelberg, K., (2012). Climate Change and its Impact on the Livelihood of Farmers and Agricultural Workers in Ghana. Preliminary Research Results. General Agricultural Workers' Union of GTUC. Friedrich Ebert Stiftung (Fes).

Nakuja, T., Sarpong, D.B., Kuwornu, J.K.M., and Felix, A.A. (2012). Water storage for dry season vegetable farming as an adaptation to climate change in the Upper East region of Ghana. *African Journal of Agriculture Research*, 7(2), 298-306.

Nankani, G. (2009). Challenges of the Ghanaian economy. http://www.ghanabusinessnews.com/2009/02/25/the-challenge-of-agriculture-in-ghana-what-is-to-be-done/. Accessed 12 July 2012.

Nelson, W. and Agbey, S. N. D. (2005). Linkages between poverty and climate change; Adaptation for livelihood of the Poor in Ghana. Technical Paper. Pp1-71.

NEST, (2004). Regional climate modelling and climate scenarios development in support of vulnerability and adaptation studies: Outcome of Regional Climate Modeling Efforts over Nigeria, NEST, Ibadan, Nigeria.

Norris, E. and Batie, S. (1987). Virginia farmers' soil conservation decisions: An application of Tobit analysis. *Southern Journal of Agricultural Economics* 19(1): 89–97.

Nyantakyi-Frimpong, H. (2013). Indigenous Knowledge and Climate Adaptation Policy in Northern Ghana, 57 Erb Street West Waterloo, Ontario N2L 6C2, Canada.

Oladosu, G., Shortle, J., Lazo, J. K. and Alber, D. (1999). Valuation of Climate Change in Computable General Equilibrium Models, http://www.soc.uoc.gr/

Olsen, J. E., Bocher, P. K and Jensen Y. (2000). Comparison of Scales of Climate and Soil Data for Aggregating Simulated Yields in Winter Wheat in Denmark. *Agriculture, Ecosystem and Environment*, 82 (3): 213–28.

Orindi, V., Ochieng, A., Otiende, B., Bhadwal, S., Anantram, K., Nair, S., Kumar, V. and Kelkar, U. (2006). Mapping climate vulnerability and poverty in Africa. In Thornton, P. K., Jones, P. G., Owiyo, T., Kruska, R. L., Herrero, M., Kristjanson, P., Notenbaert, A., Bekele, N. and Omolo, A. (eds) *Report to the Department for International Development*, ILRI, Nairobi, Kenya.

Parry, M. A. J. and Hawkesford, M. J. (2010). Food security: increasing yield and improving resource use efficiency. *Proceedings of the Nutrition Society*, 69: 592-600.

Polsky, C. and Esterling, W. E. (2001). Adaptation to Climate Variability and Change in the US Great Plains: A Multi-scale Analysis of Ricardian Climate Sensitivities. *Agriculture, Ecosystem and Environment* 85 (3): 133–44.

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A. N., Chapoto, A., Asamoah, M. and Tripp. R. (2013a). *Patterns of Adoption of Improved Maize Technologies in Ghana. Ghana Strategy Support Program (GSSP).* International Food Policy Research Institute (IFPRI).

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A. N., Chapoto, A., Asamoah, M. and Tripp. R. (2013b). *Patterns of Adoption of Improved Rice Technologies in Ghana. Ghana Strategy Support Program (GSSP)*. International Food Policy Research Institute (IFPRI).

Roudier, P., Sultan, B., Quirion, P. and Berg, A. (2011). The impact of future climate change on West African crop 9 yields: What does the recent literature say*? Global Environmental Change*, 21(3), 1073 - 1083.

Sadoulet, E. and De Janvry, A. (1995). *Quantitative Development Policy Analysis*. London: John Hopkins University Press.

Sanghi, A., Mendelsohn, R. and Dinar, A. (1998). The climate sensitivity of Indian agriculture, in A. Dinar *et al.* (eds), *Measuring the Impact of Climate Change on Indian Agriculture*, Technical Paper No. 402. Washington DC: World Bank.

Selby, H., (2010). Effects of climate change on poverty levels in Ghana. Ghanaian Chronicle. http://ghanaian-chronicle.com/features/effects-of-climate-change-on-poverty-levels-in-ghana/attachment/stick-2/. Sci/Environment | 28 July 2010 Last updated at 18:01 CET.

Seo, S. N. and Mendelsohn, R. (2008). Climate change impacts on Latin America Farmland values: The Role of Farm Type; Revista de Economia e Agronegocio, vol. 6, No. 2, ISSN 1679 – 1614.

Shalizi, Z. and Lecocq, F. (2009). *To Mitigate or to Adapt: Is that the Question? Observations on an Appropriate Response to the Climate Change Challenge to Development Strategies".* The World Bank Research Observer Advance Access published September 2, 2009. Oxford University Press.

Shephard, R.W. (1970). *Theory of Cost and Production Functions*, Princeton Univ. Press, Princeton, NJ.

Shepherd, Andrew *et al.* (2005). Economic Growth in Northern Ghana. Report prepared for DFID Ghana, Overseas Development Institute and Centre for Policy Analysis, London/Accra. Available at: http://www.odi.org.uk/resources/details.asp?id=2676&title=economicgrowth-northern-ghana.

Skoufias, E., Rabassa, M., Olivieri, S. and Brahmbhatt, .M. (2011). The Poverty Impacts of Climate Change. Poverty Reduction and Economic Management Network (PREM). Economic Premise, World Bank.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O. (2007). *Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Southworth, J. *et al.* (2000). Consequences of Future Climate Change and Changing Climate Variability on Maize Yield in the Midwestern United States. Agriculture, *Ecosystem and Environment*, 82 (3): 139–58.

SRID (2011), *Agriculture in Ghana: Facts and Figures 2010*. Ministry of Food and Agriculture, Accra.

Stanturf, J. A., Warren, M. L., Charnley, Jr., S., Polasky, S. C., Goodrick, S. L., Armah, F., and Nyako, Y. A. (2011). Ghana Climate Change Vulnerability and Adaptation Assessment. Washington: US Agency for International Development strategies and policies, by K. Stamoulis and A. Zezza. Rome.

Stige, L. C., J. Stave, K. Chan, _. (2006). The effect of climate variation on agro-pastoral production in Africa. Proceedings of the National Academy of Sciences, 103: 3049–3053.

Thornton *et al.* (2009a). Spatial variation of crop yield response to climate change in east Africa. *Global Environmental Change*, 19(1), 54-65.

Thornton *et al.* (2009b). The impact of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. *Agricultural systems* 101: 113-127.

Tonah, S. (1993). The development of agro pastoral households in Northern Ghana: policy analysis, project appraisal and future perspectives. Verlag für Entwicklungspolitik, Saarbrücken.

United Nations (1992). United Nations Sustainable Development. Conference on Environment and Development. Agenda 21. Rio de Janerio, Brazil, 3 to 14 June 1992.

Vermeulen, S. J., Aggarwal, P. K., Ainslie, A., Angelone, C., Campbell, B. M., Challinor, A. J., and Hansen, J. W. (2010). Agriculture, Food Security and Climate Change: Outlook for Knowledge, Tools and Action. CCAFS Report No. 3. Agriculture (pp. 1-16). Copenhagen: CGIAR-ESSP Program on Climate Change, Agriculture and Food Security.

Whitehead A (2006). Persistent Poverty in North East Ghana. *J. Dev. Stud.* 42(2):278–300.

Wicksteed, P.H. (1894). An essay on the co-ordination of the laws of distribution. Macmillan & Co., London. At http://cepa.newschool.edu/het/texts/wicksteed/wickess.pdf.

Winter, P., Muragi, R., Sadoulet, E. and DeJanvry A. (1996). Climate Change, Agriculture, and Developing Economies, Department of Agricultural and Resource Economics, Division of

Agriculture and Resource Economics, University of California at Berkley, Working Paper No. 785.

Wit, P. and Norfolk, S. (2014). Diligence on Land Aquisition, Benefit Sharing and Mitigation of Unintended Consequences: Case Study of Irrigation Investment in Northern Ghana. In 2014 World Bank Conference on Land and Poverty. Washington DC, 2014. The World Bank.

WMO (1992). International meteorological vocabulary, 2nd edition. Publication No. 182. Available at: www.agis.agric.za/agisweb/FIVIMS_ZA.

Wolfe, D. W., Schwartz, M. D., Lakso, A. N., Otsuki, Y., Pool, R. M. and Shaulis, N. J. (2005). Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *Internat J. Biometeorol* 49:303-309. Meteorological Organization, Geneva.

Xiao, X. *et al.* (2002). Transient Climate Change and Potential Croplands of the World in the 21st Century, Massachusetts Institute of Technology, Joint program on the Science and Policy of Global Change, Report No. 18.

Yamin, F. and Depledge, J. (2009). *The International Climate Change Regime. A guide to rules, institutions and procedure*; Pp. 20 – 73, Cambridge University Press.

Yaro, J. A. (2010). The Social Dimensions of Adaptation to Climate Change in Ghana. The World Bank Discussion paper no.15. Washington: The World Bank.

Yaro, J.A. 2006. 'Is deagrarianisation real? A study of livelihood activities in rural northern Ghana'. *Journal of Modern African Studies* 44, 1: 125-56.

Yirga, C. T. (2007). The dynamics of soil degradation and incentives for optimal management in Central Highlands of Ethiopia. PhD thesis. Department of Agricultural Economics, Extension, and Rural Development. University of Pretoria, South Africa.

Zhu, X.-G., Long, S.P. and Ort, D.R. (2010). Improving photosynthetic efficiency for greater yield. *Annual Review of Plant Biology* 61: 235-261.

Zoellick, R. B. A. (2009). Climate Smart Future. The Nation Newspapers. Vintage Press Limited, Lagos, Nigeria. Page

APPENDICES

QUESTIONNAIRES TO ASSESS THE ECONOMIC IMPACT OF CLIMATE CHANGE ON SMALLHOLDER AGRICULTURE AND ADAPTATION STRATEGIES IN SISILI-KULPAWN BASIN OF THE NORTHERN REGION OF GHANA

Name of Community: __________________________ Date of Interview:

____/____/2014 Time: _______ Household ID:__________ GPS location:

__________ N ___________

Name of Respondent:__________________________ Mobile No.________________

Age of Respondent: Under 20 ❒ 21 – 30 ❒ 31 – 40❒ 41 – 50 ❒ Over 50 ❒

Education of Respondent: No formal education❒ Primary❒ Secondary❒ Tertiary

Other (specify)__________

How many persons are in your household?

Adult Male:___ Adult Female:___ Children Male:____ Children Female ___ **Total:**

The size of all land available for farming to the farm household __________________

Number of rain-fed crop farms of the household ________

Crop & Variety	Approximate Sowing Date **(Last Season)**	Approximate Harvesting Date **(Last Season)**	Farm Size (Ha)

Number of livestock types in the household _________

Herd size:

Cattle _______ Sheep_______

Goats_______ Pigs________ Poultry Birds ________

8. Inputs used in the cultivation of the major staple crops [except land]

MAIZE INPUTS	Quantity	Unit price (GHS)	Input Cost (GHS)
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
COWPEA INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
RICE INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
MILLET INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
GROUNDNUT INPUTS			
1			
2			
3			
4			

9. Inputs used in the rearing of the types of livestock [except land]

CATTLE INPUTS	Quantity	Unit price (GHS)	Input Cost (GHS)
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
SHEEP INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
GOAT INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
PIGS INPUTS			
1			
2			
3			
4			
5			
TOTAL INPUT COST:			
FOWLS INPUTS			
1			
2			
3			
4			

5			
TOTAL INPUT COST:			

5			
TOTAL INPUT COST:			

10. Fertilizers used in the cultivation of the major staple crops

Crop	Inorganic Fertilizer						Quantity (Bags/Farm)	Unit Cost (GHS)	Input Cost Cost (GHS)	Date of Application	Mode of Application
	NPK			SOA	Urea	Other					
	15:15:15	20:20:10	Others								

TOTAL COST:

1= Broadcasting 2=Placement
3= Banding 4=Others

11. Manure used in the cultivation of the major staple crops

Crop	Organic Manure				Quantity (Bags/Farm)	Unit Cost (GHS)	Input Cost Cost (GHS)	Date of Application	Mode of Application
	Cattle, Sheep& Goat Dung	Poultry Manure	Compost	Others					

TOTAL COST:

1= Broadcasting 2=Placement
3= Banding 4=Others

12. Quantities harvested and unit prices of the major crops harvested by farm household in the last farming season

CROP	Quantity harvested (Bags/Farm)	Unit price (GHS)	Revenue (GHS/Farm)

13. Quantities sold/slaughtered and unit prices of the major livestock types by farm household in the last year

LIVESTOCK TYPE	Quantity slaughtered & sold (No./Farm)	Unit price (GHS)	Revenue (GHS/Farm)

14. Annual non-farm household income sources and levels

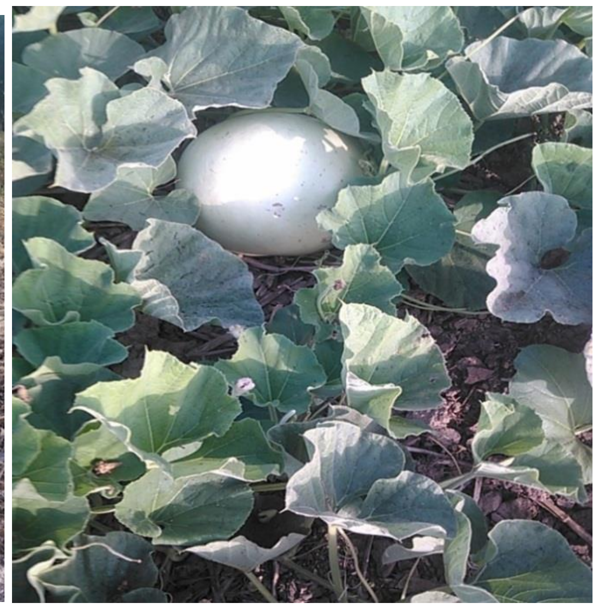
Non-farm income	Source	Amount (GHS)
January - March		
April - June		
July - September		
October - December		
Other		
Total:		

Name of Interviewer ______________________________ Signature _______________

CLIMATE CHANGE IS EXACERBATING EXISTING VULNERABILITIES OF THE POOREST PEOPLE WHO DEPEND ON SEMI-SUBSISTENCE AGRICULTURE

AGRICULTURE IN THE SISILI-KULPAWN BASIN

AGRICULTURE IN THE SISILI-KULPAWN BASIN



AGRICULTURE IN THE SISILI-KULPAWN BASIN

THE SISILI-KULPAWN RIVER