UNIVERSITY OF CAPE COAST

CLIMATE CHANGE RESPONSES, FOOD SECURITY AND PRODUCTION SUSTAINABILITY OF MAIZE-FARMING HOUSEHOLDS IN VOLTA REGION, GHANA

BY

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DECLARATION

Candidate's declaration

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

Candidate's Signature: .... Date: 08/05/2019

Selorm Akaba

Supervisors' Declaration

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

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ABSTRACT

Transforming food systems and improving production sustainability is core to achieving the sustainable development goals. This study evaluates the nexus of climate change responses, food security and sustainable agricultural practices in the Volta Region of Ghana. With a cross-sectional survey design backed by the pragmatist philosophy, primary data were collected from 733 maize-farming households using structured interview schedule. A multi-phase sampling technique was employed to select 9 administrative assemblies, 3 from each geographical zones of Northern, Middle and Southern Volta. Several analytical tools including binary logistic and multiple linear regressions, consolidated approach to reporting food insecurity, Garret factor rankings techniques, Friedman rank tests, analysis of variance, and structural equation modelling were used. Major findings indicate that though farmers produce at least two different varieties of maize in tandem, *Obatampa* is the most important variety. Important constraining factors to maize enterprise were undercapitalisation, low yield, diseases and pests outbreaks, uncertain demands, inadequate infrastructure and lack of market information. Majority (53.8%) of the households were food insecure across the region. Most maize farmers reported negative climate change effects and have adopted diversity of response strategies to avert the situation. Farmers have positive attitudes towards sustainable agriculture, which significantly influenced production sustainability. The major latent variables that significantly influenced food security were responses to climate change, livelihood diversification and attitudes and practices of sustainability. This implies that farmers could improve food security levels by practicing sustainability. Farmers should also increase their adaptive capacity to climate change through production sustainability.

KEY WORDS

Adaptive capacity

CARI Console

Food security index,

Production sustainability index

Structural equation modelling

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DEDICATION

To my children Setiam, Sevame and Sexozi, and my wife, Sedinam; you have endured my endless hours of writing. Also to my entire family, for the love and support.

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LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
ANOVA	Analysis of Variance
ASA	Attitudes towards Sustainable Agriculture
ASI	Agricultural Production Sustainability index
AVE	Average Variance Extracted
BMI	Body Mass Index
CARE	Cooperative for Assistance and Relief Everywhere
CARI	Consolidated Approach to Reporting Indicators of Food Security
CC	Coping Capacity Domain
CCA	Climate Change Adaptation
CCE	Climate Change Effect
CCR	Climate Change Response
CFCs	Chlorofluorocarbons
CFSVAs	Comprehensive Food Security and Vulnerability Analysis
CH_4	Methane
CHS	Community Household Surveillance
CIAT	International Centre for Tropical Agriculture
CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Centre
CO_2	Carbon Dioxide
CONST	Constraints to Maize farming Enterprises
CS	Current Status Domain
CSI	Coping Strategies Index

DDA	District Department of Agriculture
DDS	Diet Diversity Scores
DSR	Driving Force State Response
ENN	Emergency Nutrition Network
EPA	Environmental Protection Agency
ESA	Eastern and Southern Africa
ESI	Environmentally Sustainability Index
FAO	Food and Agricultural Organisation of the United Nations
FAW	Fall Army Worm
FCS	Food Consumption Score
FEG	Fund Evaluation Group
FES	Food Expenditure Share
FEWS NET	Famine Early Warning Systems Network
FIES	Food Insecurity Experience Scale
FS	Food Security
FSI	Food Security Index
GDP	Gross Domestic Product
GFSI	Global Food Security Index
GHG	Greenhouse Gas
GHI	Global Hunger Index
GIS	Geographic information system
GM	Genetically Modified
G_OF	Goodness of Fit index
GSS	Ghana Statistical Service

HCESs	Household Consumption and Expenditure Surveys
HDDS	Household Dietary Diversity Score
HEA	Household Economy Approach
HFES	Household Food Expenditure Share
HFSSM	Household Food Security Survey module
HTMT	Heterotrait-Monotrait
IAC	International Astronautical Congress
IBM-SPSS	International Business Machines Corporation - Statistical Product and Service Solutions
ICT	Information Communication Technology
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IPC	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPMA	Importance-Performance Matrix Analysis
IRT	Item Response Theory
ISDM	Interval standard deviation from the mean
ISFM	Integrated soil fertility management
ISSER	Institute of Social Sciences and Economic Research
JHS	Junior High School

KR	Kuder-Richardson
LCA	Life Cycle Assessment
LCS	Livelihood coping strategy
LivDiv	Livelihood Diversification
M	Mean
MAVT	Multi-attribute theory
MCDA	Multi-Criteria Decision Analysis
MDGs	Millennium Developments Goals
MiDA	Millennium Development Authority
ML	Maximum Likelihood
MoFA	Ministry of Food and Agriculture
MSL	Middle School Leavers
MV	Middle Volta
N_2O	Nitrous Oxide
NGOs	Non-Governmental Organizations
NRC	National Research Council
NV	Northern Volta
ODI	Overseas Development Institute
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squared
PCCE	Perceived Climate Change Effects
P_e	People
PHC	Population and Housing Census
P_l	Planet

PLS	Partial Least Square
PLS-MGA	Partial Least Square Multi-Group Analysis
PLS-SEM	Partial Least Square-Structural Equation Modelling
POU	Prevalence of Undernourishment
P_r	Profit
PSR	Pressure-State-Response
Q^2	Stone-Geisser Predictive Relevance
QPM	Quality Protein Maize
R^2	Coefficient of Determination
RDA	Regional Department of Agriculture
S.E	Standard Error of Estimates
SA	Sustainable Agriculture
SD	Standard Deviation
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling
SHS	Senior High School
SLS	Sustainable Livelihood Security
SOE	State of Environment
SOFI	State of Food Insecurity
SRMR	Standardized Root Mean Squared Residual
SSA	Sub-Saharan Africa
SSE	Sum of Squared Error
SSO	Sum of Squared of Original Sample
SUSAG	Sustainable Agricultural Production Practices

SV	Southern Volta
UN	United Nation
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nation's Children Fund
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VAM	Vulnerability Analysis and Mapping
VIF	Variance Inflation Factor
W	Coefficient of Concordance
WCA	West and Central Africa
WFP	World Food Programme
WHO	World Health Organization
WOCAT	World Overview of Conservation Approaches and Technologies
YPARD	Young Professionals for Agricultural Development

CHAPTER ONE

INTRODUCTION

Agricultural production holds a central role in ensuring food security of households throughout Ghana as it constitutes the main source of livelihood (food and income) and provides employment for 60 percent of the population (WFP, 2016). Food availability in in country is attained through a combination of domestic production of major staples such as maize, yam, cassava and rice, and significant importation of rice. Maize, as a food security crop, is one of the three most important staples commonly consumed across the country (WFP, 2016). Continuous availability and accessibility as well as efficient utilisation of such food is therefore paramount to the achievement of food security goals of sustainable food systems with zero hunger, increase productivity and income and adequate access all year round.

Agriculture continues to play a key role in sustainable growth and development of Ghana. It also plays a fundamental function in contributing to food and livelihood security among households in the country, many of whom depend either directly or indirectly on agriculture for the bulk of their livelihood. As part of the Post-2015 Development Agenda, a new set of transformative and universal Sustainable Development Goals (SDGs) has been adopted by the 193 member countries of the United Nation. Food security featured prominently in both the Millennium Development Goals (MDGs) and the SDGs. Besides food security, targets relating to nutrition, sustainable agriculture, sustainable management of natural resources and rural development are conspicuously highlighted in the SDGs, placing the transformation of food systems and working with natural resources at the heart of the new global goals (Sachs, 2015). Sustainable development, of which sustainable agriculture constitutes a key part, is one of the main long- term priority objectives of Ghana as it focuses on enhancing the quality of life of the citizenry.

The threat of climate change represents a serious challenge to the economic and socioeconomic development of many developing and least developed countries. Many developing countries heavily rely on climate sensitive natural resources to foster economic growth and development and to advance food security for their population. The agricultural sector produces the food for the population and also provides an important source of economic livelihood for about one third of the global population (FAO, 2016; Kornher, 2018).

This chapter presents the background to the study. Besides, the chapter covered the statement of the research problem, objectives of the study, research questions, significance of the study, limitations and delimitations of the study, and operational definitions of concepts and terminologies used in the study.

Background to the Study

Though Ghana has successfully registered a sustained growth in per capita food production since 1990 compared with many countries in Sub-Saharan Africa (ISSER, 2010), there have been increasing concerns about the performance of the country's agricultural sector in recent times given that it is one of the major backbones of the country's economy. According to Ghana Statistical Service at basic prices, agriculture's contribution as a percentage of GDP was 31.8 in 2009. However, by 2012, this figure has declined to 22.7 before increasing marginally in 2013/2014 cropping season to 23.0 (GSS, 2014). The general decline of the agricultural sector's contribution to GDP has largely been attributed to the expansion of the oil sector (ISSER, 2014). However, before the introduction of the oil sector to the economy, the World Food Programme (WFP, 2010) reported that the sudden decline in agriculture's share of GDP can be partly attributed to the heavy reliance on traditional crops and outmoded production practices.

World Bank (2008) posits that agriculture will continue to be a fundamental instrument for sustainable development and poverty reduction in many countries worldwide. For example, it is estimated that without developing agriculture and making sustained progress in food crop production, rapid overall economic growth and poverty reduction targets are impossible to achieve (World Bank, 2007a). Some authors maintain that sustainable agriculture is an important precondition for socioeconomic development (Memon, 1993; Gill, Mustafa, & Jehangir, 1999; Malik, 2003; Baig & Khan, 2006; Mahmood & Malik, 2007).

Since its introduction over 5 centuries ago, maize (*Zea mays* L.) has established itself as the most important cereal in terms of production and use in Ghana. In no time, maize attracted the attention of commercial farmers, even though it never achieved economic importance as compared to traditional plantation crops such as oil palm and cocoa. Maize accounts for more than 50 percent of total cereal production and about 27 percent of total arable land in the country. It is the second most important commodity crop in the country after cocoa (MiDA, 2010; MoFA, 2012; Ragasa, Chapoto, & Kolavalli, 2014, Nurudeen, Larbi, & Hoeschle-Zeledon, 2015, Darfour & Rosentrater, 2016, Oppong, Ewool, Ribeiro, Obeng-Antwi, & Ennin, 2017).

Maize is grown over a wider range of altitudes and latitudes than any other food crop and in many different types of soils. Maize was introduced from the centre of origin in Mexico into different growing conditions in the tropical, subtropical and temperate regions (Rebourg et al., 2003; Damsteegt & Igwegbe, 2005; Dubreuil et al., 2006). Maize was first introduced into Africa by Portuguese traders in the 16th century (Shephered et al, 2010), and also from the Caribbean, Central and South America (Damsteegt & Igwegbe, 2005). Subsequent introductions have been made from Europe and Asia, (McCann, 2001). Maize remains the most important cereal staple, grown in all agro-ecologies across Ghana (Armah, 2014; Oppong et al., 2014).

The average global area for maize for 2016/2017 production was about 186.86 million hectares with production output of 1,078.56 million metric tonnes (USDA, 2018). In sub-Saharan Africa, 38 million metric tonnes of maize are produced on around 25 million hectares, predominantly on smallholder systems and primarily for food (Smale, Byerlee, & Jayne, 2011).

At the global level, the main thrust for dramatic growth in production and yield response is the exponential increase in demand for maize for both food and non-food uses. It is extensively higher than other cereals and increased by more than four folds from 189 million metric tonnes in 1961 to 771 million metric tonnes in 2010. For instance, in the same year, it accounted for more than 40 percent of the global demand for major cereals. Largely, much of the increase in demand for maize came from the developing regions where it increased to more than six folds, from 65 million tonnes to 427 million tonnes, during the same period (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Maize is an important source of food and nutritional security for millions of people in developing countries, especially in Africa and Latin America (Shiferaw, Prasanna, Hellin, & Banziger, 2011). In Ghana, the contribution of maize to household food security cannot be overemphasised. Despite the economic importance of maize in the country, its average yield of 1.5 to 1.7 metric tonnes per hectare is woefully below its potential yield of 5.0 to 6 metric tonnes per hectare (MiDA, 2010). In addition to the shortfall in domestic supplies to fulfil demands, maize consumption is projected to grow at a compound annual growth rate of 2.6 percent. Further, beyond these projected figures for household consumption, there is considerable unfulfilled demand for processed maize uses and for the growing animal feed sector within Ghana (Armah, 2014).

A dedicated global goal, SDG2, based on a comprehensive approach to tackling food insecurity and malnutrition while promoting sustainable agriculture is an important step to achieving zero hunger and ushering in a new era of sustainable development. Feeding a growing global population while nurturing the planet will be a monumental challenge, but it can be achieved by transforming food systems and agriculture, embracing sustainable farming practices. Given the mounting pressure on global ecosystems, the food production increase must be achieved in a sustainable and environmentally sound way (FAO, 2016).

The definition of agricultural sustainability varies by individual, discipline, profession, and area of concern. The goal of sustainable agriculture is to meet present societal needs without compromising the ability of future generations to meet their own needs. Practitioners of sustainable agriculture seek to integrate three main objectives into their work by having a healthy environment, economic profitability, and social and economic equity. Thus, farm and food systems must be able to respond effectively to environmental and economic stresses and opportunities (Carter, et al., 1993; Feenstra, 2018).

Sustainability in agriculture is a complex concept and there is no common viewpoint among scholars about its dimensions. Nonetheless, various parameters for measuring agricultural sustainability have been proposed. For any study on sustainable agriculture, the question arises as to how agricultural sustainability can be measured. Hayati, Ranjbar and Karami (2011) argued that indicators used for agricultural sustainability should be location specific. They should be constructed within the context of the contemporary socioeconomic and ecological situation.

It is widely assumed that ongoing changes in climatic conditions will have an adverse effect on agriculture production in Africa (Maddison, 2007, Stern 2006, Kurukulasuriya, 2006). While the impact of climate change is felt predominantly through changes in the timing, frequency, and intensity of rainfall events - and in the distribution of these events through a season - and not merely changes in annual averages, most macroeconomic and agricultural production data are only available on an annual basis.

Climate change effects, including changing temperature and rainfall patterns, and a larger variability in weather patterns, negatively impact global food security. Although there is considerable uncertainty about the effect of climate change on the food system, climate change is expected to adversely affect agricultural yields and the conditions of natural resources, for instance by impelling soil retrogression and degradation. In addition, agricultural production and land use change are also major emitters of greenhouse gases (GHG). Overall, agriculture and deforestation account for 25 percent of carbon dioxide, 50 percent of methane, and more than 75 percent of nitrogen (fertilizer application) emissions (Pinstrup-Andersen, Watson, Frandsen, Kuyvenhoven, & Von Braun, 2011; Kornher, 2018).

Selected studies identify Africa as a region highly vulnerable to climate change effects. The increase in temperature is expected to be between 3–4°C until the next century. Also, rainfall patterns will change leading to a reduction in annual precipitation of 20 percent in selected areas (IPCC, 2016, Kornher, 2018). Changing climate patterns, increasing weather variability and a higher frequency of extreme events already have direct impacts on agricultural production, productivity, and the stability of the food system. Climate change will reduce crop yields and in consequence will increase food prices forcing people to reduce their calorie intake or the nutritional quality of the diets. It is projected that agricultural yields in rain-fed agricultural systems will be exposed to increasing water stress and could decrease by around 30 percent by 2050 in the worst-case scenario (Schlenker & Lobell, 2010; Kornher, 2018).

Africa is considered the most vulnerable and disproportionately affected region in the world in terms of climate change. Farming is undertaken mainly under rain-fed conditions, increasing land degradation, and low levels of irrigation – 6 percent compared to 38 percent in Asia (FAO, 2011). The contribution of agriculture to the gross domestic product in Africa is far higher than in developed regions. This is perhaps nowhere more obvious than in sub-Saharan Africa, where economies are extremely sensitive to environmental and/or economic shocks in the agricultural sector.

Despite the transition to industry and services-oriented economy of Ghana, 45 percent of the workforce still depends on rain-fed agriculture (USAID, 2017). The rain-fed nature of agriculture underlines the importance of the timing and amount of rainfall that occurs in the country. Heavy dependence on rainfall indicates that climate extremes such as drought or flood can cause significant food security, health and economic threats to the entire population (Cheung et al, 2008).

Beside the economic role, agriculture holds other social and environmental functions, thus impact on the social equilibrium, preservation of cultural landscape and cultural heritage, maintenance of ecosystem functions, maintenance of biodiversity, preservation of natural values (Klemenčič et al., 2008 cited in Erker, et al., 2013). European Commission (2001), stated that multifunctionality of agriculture is based on the fact that agriculture is not only the production of food and therefore the other two roles need to be considered as well. The first is the environmental role, which includes numerous landscape characteristics and environmental values and therefore contributes to formation of agricultural heritage. The second is the socio-economic role where agriculture contributes to the settlement of rural areas as well as to the balanced spatial development, it provides the jobs in farming and food industry.

To feed the world's 9 billion people in 2050, we urgently need to adopt the most efficient farming techniques available (De Schutter, 2011). Scientific evidence demonstrates that agro-ecological methods outperform the use of chemical fertilizers in boosting food production where the hungry live (De Schutter, 2011). Agro-ecological projects have shown an increase in average crop yield 80% in 57 developing countries, with average increase of 116% for all African projects. Projects conducted in 20 African countries demonstrated a doubling of crop yields over a period of 3 – 30 years.

Conventional farming relies on expensive inputs. It fuels climate change and it is not resilient to climate shocks. Practicing sustainable agriculture is considered to be a better bet for combating climate change. Many of the challenges facing agriculture will require more integrated application of existing science and technology development as well as new approaches for agriculture natural resource management (McGee, 2008).

Agriculture contributes 60 and 50 percent of global anthropogenic emissions of CH_4 and N_2O respectively. The natural resources base on which agriculture depends has been declining faster in recent times than any other time in history due to increased global demand and degradation. Degradation of ecosystem functions constrains production and may limit the ability of agriculture systems to adapt to climatic and other global changes in many regions. Sustainable agricultural practices are part of the solution to current environmental change (McGee, 2008).

The impact of climate change threatens to escalate in the absence of adequate safeguards and there is a need to promote the integrated and sustainable management of resources and ecosystems and take mitigation and adaptation actions in achieving the SDGs (Department of Economic and Social Affairs, 2013). The need to stimulate economic growth, reduce poverty, and increase sustainable agricultural production to feed a rapidly growing population is placing more pressure on the natural resource base in developing countries. The deterioration of natural resources, in turn, impedes efforts to improve living conditions. This dilemma, however, has stimulated a growing commitment to sustainable development among tropical and non-tropical countries alike, with special concern for the world's humid tropics (Carter, et al., 1993). Farmers need a choice of options to respond to challenges, given their diverse needs and resources, and to address the increasing complexity of stresses under which they operate (McGee, 2008).

Statement of the Problem

The world needs to produce at least 50% more food to feed 9 billion people by 2050. But climate change could cut crop yields by more than 25%. The land, biodiversity, oceans, forests, and other forms of natural capital are depleting at unprecedented rates. Unless we change how we grow our food and manage our natural capital, food security – especially for the world's poorest – will be at risk (World Bank, 2016). As reported by Shiferaw, Prasanna, Hellin, and Banziger (2011), maize is the basis for food security in some of the world's poorest regions in Africa, Asia, and Latin America. However, yields in these parts of the world are extremely low. The demand for maize in the developing countries is projected to double by 2050 (Rosegrant, et al., 2009). How can measures be taken to accelerate productivity growth in the maize industry to meet the growing requirements of maize which serve as food security for many.

Studies on maize production in Ghana mostly focused on promotion and adoption of new technologies, export potential and postharvest handling and losses. There are limited empirical literature on estimating production sustainability and the contribution of maize enterprise to food security. The gap in literature on the interrelationships between food security and maize production sustainability in Ghana needs to be filled for informed decisions and policy strategies to be implemented. In addition, it is hard to come by any study on how farm level sustainable production practices in the various agro ecologies influence household food security in the midst of exogenous factors like climate change.

In other studies, farmers in different ecologies were treated as though their constraints and opportunities are the same. Majority of farm production studies stratify farms only by farm characteristics. Such methods presume that all farms were producing under similar environmental conditions and as such, differences in the output and productivity among farms are mostly due to the scale of operation (Addai & Owusu, 2014). This should not be the case in traditional agriculture, which relies heavily on the underlying agro-ecological conditions (Okike et al., 2004).

Attempts at improving African agriculture have focused almost exclusively on technical intervention and policy prescriptions for increasing agricultural productivity centre on the promotion of high input packages that consist of technologies, high yielding varieties, agrochemicals and subsidies (IAC, 2004; Eicher, 2003; Dan-Azumi, 2011). The diversity of the ecologies, farmer's inputs, environment and biodiversity are seldom taken into account in agricultural planning. Many agricultural programmes and interventions on the continent lack context and ignore the poverty and weak purchasing power of most small-holders, a problem compounded by weak infrastructural support for sustainable small-holder agriculture (Scoones, Degrassi, Devereux, & Haddad, 2005; Dan-Azumi, 2011).

Technical intervention in African agriculture has consistently failed to ensure food security on the continent (Cowan & Shenton, 1996). The logic and method of the global food systems and its ability to meet global food demands in a sustainable manner have been seriously questioned (Altieri, Rosset, & Thrupp, 2001). Opponents of conventional agriculture argue that it ignores issues of sustainability, attributes productivity to a single set of factors and fails to acknowledge other possibilities. The growing demand for food for an increasing population in a time of severe biophysical limitations is threatening natural resources as people strive to get most out of land already in production. The result includes the following damages: arable land lost to erosion, salinity, desertification and urban spread, water shortages, disappearing forests and threats to biodiversity (Dan-Azumi, 2011)

In spite of the evident importance of sustainable role of agriculture, scientific and strategic studies that would indicate specific prospects, challenges and impacts to which policy decision makers should pay more attention are rare. While some authors argued that sustainable agriculture could lead to food security, others are of the opinion that in their efforts to achieve food security, farming households may employ practices that may be inimical to sustainability. This study therefore sought to assess the nexus of food security and production sustainability of the maize farmers in the Volta Region of Ghana.

Objectives of the Study

General objective

The research generally sought to assess climate change responses, food security and production sustainability nexus of maize farmers in the Volta Region of Ghana.

Specific objectives of the study

Specifically, the study sought to:

1. describe the state of maize production sustainability in the Volta Region;
2. evaluate contribution of maize production to food security among Maize farming households;
3. evaluate climate change response strategies adopted by maize farmers; and
4. develop model for climate change responses, food security and production sustainability among maize farmers in the Volta Region of Ghana.

Research Questions

The study was also guided by the following research questions:

1. What is the state of maize production sustainability in the Volta Region?
2. How does maize production contribute to achieving food security in the farmers' households?
3. What is the level of adaptive capacity of the maize farmers to climate change effects?
4. How could maize production sustainability and adaptive response to climate change influence food security of Maize farming households?

Significance of the Study

Almost 80 percent of the world's extreme poor live in rural areas where most are dependent on agriculture. Agriculture is the single largest employer in the world. Agricultural growth in low-income and agrarian economies is at least twice as effective as growth in other sectors in reducing hunger and poverty (FAO, 2016).

As established by Ivanic and Martin (2017), increasing GDP by identical amounts through increasing productivity in different sectors would lower poverty most if the productivity gain is in agriculture. Even when the size of the productivity gain in agriculture is not adjusted for the lower share of agriculture in the majority of developing countries, poverty reductions through improvements in agriculture are frequently at par with the gains from equally sized productivity gains in all other sectors. Any attempt to improve economic sustainability in the agricultural sector will therefore contribute immensely towards achieving poverty reduction.

In Ghana, agriculture is important for food security. It produces the food people eat, and it is the primary source of livelihoods for majority of the working populace and their households. Improving the efficiency and sustainability of smallholder farming is the main pathway out of poverty in using agriculture for development (World Bank, 2007b). Taking initiatives to promote sustainability in the agricultural sector is one of the most effective ways of reducing perpetual poverty, hunger and malnutrition.

The economy of Ghana is dominated by the agriculture sector. Agricultural resources like all other economic resources are scarce and have alternative uses. To justify the application of a resource in a particular venture, like maize, farming on a sustainable bases, the returns on the resources must be in excess of the cost of using those resources and must do so more than it occurs in the other alternative uses to which it can be put. Known levels of efficiency and their determinants can help policy makers to effect changes that could lead to increased efforts to put the scarce resources into areas that mostly need these resources for optimum returns.

Sustainable agricultural development requires increased output per unit land and per worker (Dzadze et al., 2012). Increasing the efficiency of input use becomes a viable alternative means of increasing output. Periodic assessment of farm level efficiency and its determinants remains an important step to aid improvement in the sustainability of the farm firm. To improve efficiency in the maize enterprises in the region, current levels of efficiency must be known.

Maize is the largest staple crop in Ghana and contributes significantly to consumer diets. It is the number one crop in terms of area planted, accounts for 50 to 60 percent of total cereal production, and represents the second largest commodity crop in the country after cocoa. It is one of the most important crops for Ghana's agricultural sector and for food security (Armah, 2014). It serves as common source of livelihoods for farmers engaged in its production.

In the Volta Region of Ghana, the cultural connotations attached to maize as the main staple food cannot be over emphasised. Given the resources and technology available, examining the extent of food security and production sustainability while adopting strategies to reduce negative climate change effects can provide useful insights on how to improve the conditions of Maize farming in the region. It is important to understand farmers from the Volta Region because of their significant role in the national food system, and their contribution as well as vulnerability to climate change. As noted above, maize farmers will need to adapt to climate change in order for agriculture and the food system to remain resilient.

The level of efficiency and sustainability of maize farmers have important implications for the choice of development strategies since over 60 percent of farmers rely on it for their livelihoods (Owuor & Shem, 2009). When it is established that there are differences in efficiency and sustainability among the agro ecological zones, the different strategies could be opted for improving the maize production in the region. The results will also be important in extension work as it will highlight farm and farmer characteristic more likely to enhance the implementation of the strategies that can improve sustainable livelihoods among the farmers in the region.

The study will also add to literature on how maize contributes to household food security. One of the principal aims of every farmer is to produce to feed her or his family and sell the rest for other livelihoods. It is therefore prudent to investigate this rationale of how food security is influenced by the maize production sustainability.

Further, the study will help policy makers, as farm and farmer characteristics observed, to influence food security. In addition, findings on production sustainability among maize farming-households will be used to formulate policy recommendations that will help policy makers to develop strategies that improve Maize farming in the region. NGOs, private and public agencies will also be able to direct their investments towards the promotion of those farm and farmer characteristics positively influencing food security and sustainable agriculture.

Sustainable use of natural resources is essential to ensure the long-term survival of our planet and its people. The hundreds of millions of people who manage agricultural and food systems constitute the largest group of natural resource managers on earth. The daily management decisions of those who farm, keep livestock, fish, manage forests, and run agribusinesses are key to global food security and the health of the world's ecosystems. Sustainable performance measures can be used as input for policy tools and stimulate better integration of decision-making. The study will generate new evidence and decision-making support tools to help decision makers create an enabling environment for farmers, especially maize farmers, to engage in sustainable agricultural practices. Sustainability indices can encourage public participation in sustainability discussions.

Agriculture's importance cannot be overemphasised from a food security perspective, nor its vital role in assisting the country to enhance and maintain economic growth and sustainable development. Understanding changes in agriculture taking place in response to climate changes is therefore of utmost importance to the farming sector from the dual perspective of food and nutrition security, and sustainable development. It is therefore necessary to consider interrelationship to enable the system as a whole to function efficiently and to adapt to changing conditions, which is a primary requisite to survival.

The current trend of unpredictability in climate variables indicates that latent impacts of climate change are generally critical. The climate change effects in Ghana are already being felt to be prevalent and precarious. Farmers therefore need to adjust to the changing patterns and respond accordingly with various degrees of resiliency in their farming practices and investment decisions. The agricultural sector in the various agro-ecologies of the Volta Region is highly vulnerable to climate change, with the possibility of worsening loss of livelihoods and biodiversity in the region. Extreme rainfall patterns, recurrent but unpredictable droughts, higher temperatures and low soil fertility are common features of the environment in which farming households engage in their livelihood activities.

A synthesis of the empirical evidence from other parts of the country, and all of the world, on the vulnerability of the poor to various climate risks and shocks, as well as their lack of capacity to access physical, financial and social resources, depends so much on the environment where climate change is more pronounced. Incorporating climate risk assessment in agricultural production among farming households and how new climate driven tools can help farmers and stakeholders will contribute immensely to better understanding and managing climate induced risks and uncertainties. The extent and rapidity at which adaptations have been made to climate changes that have already happened or are inevitable should provide some guidance in assessing the likelihood of future adaptations and will help to identify those obstacles to adaptation that must be removed if future damages are to be limited (Repetto, 2008).

This study is also a concrete contribution towards reaching a set of the SDGs, especially SDG1 (No Hunger), SDG2 (No Poverty), SDG13 (Climate Action), and

SDG15 (Life on Land), since the topic permeates all these themes. It is believed that the outcomes of the study will inform policy strategies for achieving the said SDGs.

Operational Definition of Terms

Farm household: is defined based on the arrangements made as individual persons or groups, for providing themselves with food or other essentials for living. Thus, farm household could constitute one person, who makes provision for his or her own food or other essentials for living without combining with any other person to form part of a multi-person household. It could also comprise a group of two or more persons living together who make common provision for food or other essentials for living. These persons in the group may however pool their incomes and to a degree have a common budget. Additionally, in Ghana, the 2000 Population and Housing Census (PHC) described a household "as a person or group of persons who share the same housekeeping arrangements and are catered for as one unit, thus a house can include several households" (GSS, 2010).

Food security: when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life at the household level (FAO, 1996). A family is food secure if it has sufficient, safe and nutritious food throughout the year so that all members can meet their nutrient needs with foods they like or prefer for an active and healthy life. Food security is linked to food intake at the individual level, and food availability at a household level. Food security is greatly influenced by physical, economic, socio-cultural, gender and ethnic factors as well as natural resources; and could be chronic or transitory. This has direct and indirect effect on the health and the behaviour of the people (FAO, 1996, 2002; ODI, 1997; Young et al., 2001, Sah, 2002, Opsomer et al., 2003; Nord et al., 2005).

Food secure household: the household is able to meet essential food and non-food needs without engaging in atypical coping strategies (WFP, 2015).

Marginally food secure household: the household has minimally adequate food consumption without engaging in irreversible coping strategies; unable to afford some essential non-food expenditures (WFP, 2015).

Moderately food insecure household: the household has significant food consumption gaps, or marginally able to meet minimum food needs only with irreversible coping strategies (WFP, 2015).

Severely food insecure household: the household has extreme food consumption gaps, or has extreme loss of livelihood assets will lead to food consumption gaps, or worse (WFP, 2015).

Sustainable production: an integral system of growing plants and breeding animals. According to the geographic characteristic of the farming area which in the long term enables the sufficient amounts of food for humans and animals, the enhanced environment and natural resources, which are crucial for agriculture. Most optimal use of non- renewable resources and the resources on farms, natural biological processes, economic vivacity of farming and it improves the quality of life of farmers and the overall society (Erker, et al., 2013). Sustainability refers also to the many characteristics of an ostensibly sustainable practice or system that are responsible for endowing that practice or system with the self-sufficiency, resilience and balance that allow it to endure over time (FAO, 2015).

Livelihood diversification: refers to the process by which the presence of multiple income sources is created (Minot, Epprecht, Anh , & Trung, 2006). This study uses the sectoral approach, where a distinction is made between farm and nonfarm activities of farm households. This study uses the sectoral approach, where a distinction is made between on-, off- and non-farm activities of farm households.

Pluriactivity: is defined as the phenomenon of farming in conjunction with at least one other gainful livelihood activity, whether on- off- or non-farm (Barrett, Reardon, & Webb, 2001; Reardon, Berdeque, & Escobar, 2001).

On-farm or agricultural livelihoods: refer to all livelihood activities on one's own property, regardless of sectoral or functional classification; it is usually self-employment (Barrett, Reardon, & Webb, 2001; Reardon, Berdeque, & Escobar, 2001).

Non-farm or non-agricultural livelihoods: refer to all activities outside the agricultural sector, regardless of location or function (Barrett, Reardon, & Webb, 2001; Reardon, Berdeque, & Escobar, 2001).

Off-farm or away from home livelihoods: refer to all activities away from one's own property, regardless of sectoral or functional classification. This could be wage or self-employment sources (Barrett, Reardon, & Webb, 2001; Reardon, Berdeque, & Escobar, 2001).

Livelihood outcomes*:* Livelihood outcomes are the results of livelihood strategies generated through assets and capabilities. Livelihood outcomes are both tangible and intangible that households attain such as food, housing, education, and better health, accumulation of assets, savings and greater social influence (Hendriks, Drimie, Chingondole, & Merzouk, 2009).

Adaptive strategies: Coping strategies become adaptive strategies when the household comes to depend on that strategy for all or part of its basic needs for longer period of time. The use of a strategy that initially started as a short-term means of mitigating negative impacts has now become the main method to access basic needs (Hendriks, Drimie, Chingondole, & Merzouk, 2009)

Resilience: the ability of a household to absorb effects of shocks and stresses without experiencing any negative impacts or resist and recover to an acceptable standard of living after experiencing shocks or stresses (Hendriks, Drimie, Chingondole, & Merzouk, 2009).

Organisation of the Study

The study is organised into eight chapters. Chapter one covered the general introduction to the study and includes the background to the study, statement of the research problems, objectives of the study, research questions, significance of the study as well as operational definition of key concepts and terminologies adapted for the study. It also outlines the organisation of the study. The second chapter presented review of related literature. It also highlighted the schematic conceptual framework developed and the hypotheses formulated based on the conceptual framework. Chapter three discussed the research methodology by detailing the design and philosophy guiding the study, the sources of data and data processing procedures, and the framework for data analysis. The state of maize production sustainability in the study area was discussed in chapter four. In satisfying the target research question in this chapter four, the findings of farm- and farmer-specific characteristics, constraints to maize production ad postharvest handling, livelihood diversification, as well as attitudes towards sustainable agriculture and maize production sustainability were discussed. The empirical findings of prevalence of food insecurity and related farm- and farmer specific determinants were discussed in chapter five. Chapter six provided results and discussions on climate change response strategies and its associated factors and perceptions. This is followed by the seventh chapter, which dwelled on development of models for improving climate change responses, food security and maize production sustainability. Using the structural equation modelling approach, this chapter had several diagnostic assessment of the data before conducting partial least square analysis to test the various path linked hypotheses. The last chapter, chapter eight, summarised the findings and concluded the study. Implications and recommendations for further studies were also presented.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

The focus of this study is to assess the pattern and interrelationships between climate change responses, food security and production sustainability among maize growing households in the Volta Region of Ghana. This chapter is dedicated to the concepts, theories and empirical literature related to the three main issues of the study. These are climate change responses, food security, and production sustainability. Under the theoretical literature review, issues such as measurement, indicators and determinants of food security, climate change and production sustainability are captured. The review of empirical literature covers the debate and the nexuses between climate change and food security, climate change and sustainable agriculture, and food security and sustainable agriculture, which have been examined by other researchers.

Concept of Climate Change

Climate change refers to changes or prolonged variations in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). Niasse (2005) also refers to climate change as any significant change or variation of natural or anthropogenic origin observed over a long period.

United Nations Framework Convention on Climate Change (UNFCCC), in a similar manner, defined climate change as a prolonged shift in climate, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable periods (Levina & Tirpak, 2006). This definition, like the IPCC's, makes a distinction between climate change 'that is change in climate attributable to human activities altering the atmospheric composition of the globe and climate variability, change in climate attributable to natural causes. That is according to the UNFCCC, climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is, in addition to natural climate variability, observed over comparable time periods (UNFCCC, 2011).

From the perspective of reducing vulnerability and facilitating adaptation, it may be unnecessary to divorce climate change from climate variability. This is because climate change impacts are not significantly different from impacts from climate variability. Therefore, adopting IPCC's and UNFCCC's concept of climate change, the term is used in this work to refer to the observed and projected increase in average global temperature, and the associated impacts, including; an increase in extreme weather events; melting of icebergs, glaciers and permafrost; sea level rise; and changes in the timing and amount of rainfall (Atanga, 2014).

Recent literature suggests that, in the tropics and subtropics where some crops are already near their maximum temperature tolerance and where dry land, non-irrigated agriculture predominates, yields will tend to decrease with even nominal amounts of climate change (IPCC, 1998). The literature tends to project further that positive effects on agriculture would be concentrated in high latitudes and negative effects in lower latitudes, precisely where problems of hunger already exist (Ahene, 2003).

Climate Change in the World

The earth's climate has significantly increased in the last couple of decades. In the past 1400 years, the 30-year period between 1983 and 2013 had the highest average temperature increase. Combined land and ocean surface temperature data confirmed that between 1880 and 2012, the temperature has increased 0.85 °C (with a range of 0.65–1.06 °C) (IPCC, 2014; Zolnikov, 2018). These changes have been primarily due to ocean warming, which has absorbed 90% of accumulated energy between 1971 and 2010. Ocean warming occurs near the top 7 meters of water, which has increased 0.11 °C (IPCC, 2014). Precipitation rates have also changed – high salinity occurs in areas with high evaporation rates (e.g. ocean surface), while low salinity occurs in other areas that experience higher levels of precipitation, resulting in more fresh water (Zolnikov, 2018).

Another measurable change is through ocean uptake of carbon dioxide (CO_2), which causes ocean acidification. These changes are confirmed by lower pH levels in the ocean surface water, which have decreased by 0.1 pH and increased in 26% acidity (measured as hydrogen ion concentration). More obvious effects of climate change are visually available with melting glaciers, diminished snow cover, decreased Arctic sea-ice each consecutive season, and rise in sea level. These changes are primarily brought about by humans and are exacerbated by economic and population growth (IPCC, 2014, cited in Zolnikov, 2018). Anthropogenic greenhouse gas emissions, comprised of carbon dioxide (81%), methane (11%), nitrous oxide (6%), and fluorinated gases (3%), have steadily grown since the preindustrial era. Since 1990, these emissions have increased approximately 7%, though fluctuating based on a myriad of influences from the year, such as a cold winter, fuel demand, vehicle miles travelled, and more (IPCC, 2014, cited in Zolnikov, 2018). Generally, electricity production makes up most greenhouse gases at 30 percent, while transportation or burning fossil fuels contributes 26 percent. The rest is made up of industry (21%), commercial and residential (12%), agriculture (9%), and land use and forestry (11%) (Zolnikov, 2018).

Carbon dioxide comes from humans burning coal, natural gas, oil, solid wastes, trees and wood products, and through chemical reactions. It is removed from the atmosphere through the biological carbon cycle by being absorbed into plants. However, it is not all being sequestered by plants. About 40% of carbon dioxide emissions from anthropogenic sources are in the atmosphere and 30% is in the ocean, with the rest accumulating on land through plants (IPCC, 2014; Zolnikov, 2018). The atmospheric carbon dioxide contributes to greenhouse gases, while the carbon dioxide in the ocean causes ocean acidification. While this accumulation has slowly but steadily occurred, nearly half of carbon dioxide emissions since 1750 have happened in the last 40 years (IPCC, 2014; Zolnikov, 2018). While significantly less, the other pollutants contributing to greenhouse gas emissions are also detrimental. Sources of methane come from coal, natural gas, and oil production and transportation as well as livestock and solid landfill waste. Atmospheric methane increased by two to three times the amount since the 1700s, but decreased by 6% between 1990 and 2014 (EPA, 2016; Zolnikov, 2018). Methane is an important greenhouse gas because it affects the troposphere and stratosphere by affecting ozone, water vapour, hydroxyl radical, and other compounds. Moreover, it has an estimated 21–36 times the heating or global warming potential of carbon dioxide by mass (Zolnikov, 2018). While methane only accounts for 11% of greenhouse gases, it is responsible for roughly 20% of the climate shift (Kirschke, et al., 2013; Zolnikov, 2018). On the other hand, nitrous oxide is a naturally occurring gas in the atmosphere, although increasingly so because of human activities. Nitrous oxide occurs during the combustion of fossil fuels and solid waste and through agriculture and industrial transportation. However, agriculture soil management accounts for 79 percent of all nitrous oxide emissions. Between 1990 and 2014, nitrous oxide emissions have decreased by 1 percent. Unfortunately, concentrations are projected to increase 5 percent between 2005 and 2020 due to an increase in agriculture and food production (Zolnikov, 2018).

Unlike nitrous oxide, fluorinated gases are completely manmade. Fluorinated gases contribute the least to the greenhouse gas total, but can persist in the environment for thousands of years. These pollutants are the most potent out of all the greenhouse gases. These gases consist of four categories, including hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride. They are emitted from a variety of industrial processes, but primarily aluminium and semiconductor manufacturing. Fluorinated gas emissions have increased 77 percent between 1990 and 2014 and are projected to expand to approximately 141 percent in 2020. Though persisting at different levels, carbon dioxide, methane, nitrous oxide, and fluorinated gases remain in the atmosphere long enough to become mixed, thereby affecting everyone worldwide regardless of the origin of the gas (IPCC, 2007; EPA, 2016). The amount of emissions is exacerbated by economic and population growth, which ultimately contributes to climate change and the outcomes experienced by people (IPCC, 2014).

Dimension of Climate Change

The various dimensions of climate change provide the framework for dialogue and actions around climate change. This is meant to review relevant components relatively humanistic, socio-cultural, ecological or environmental, and governance and political dimensions. Since these components are interrelated, the reviews on these dimensions have similar features.

Human dimensions of climate change

Over the last century, the temperature of our planet has gradually increased. Human activities have modified atmospheric constituents that absorb and scatter radiant energy within the thermal infrared range, thereby contributing to increased greenhouse gas concentrations. Greenhouse gases are a conglomeration of water vapour, carbon dioxide, methane, nitrous oxide, fluorinated gases, and ozone. Humans are largely responsible for this temperature shift. Burning fossil fuels and deforestation have increased carbon dioxide concentrations, while agriculture and livestock management (e.g. manure and fertilizers) have led to elevated levels of nitrous oxide and methane, respectively (Zolnikov, 2018).

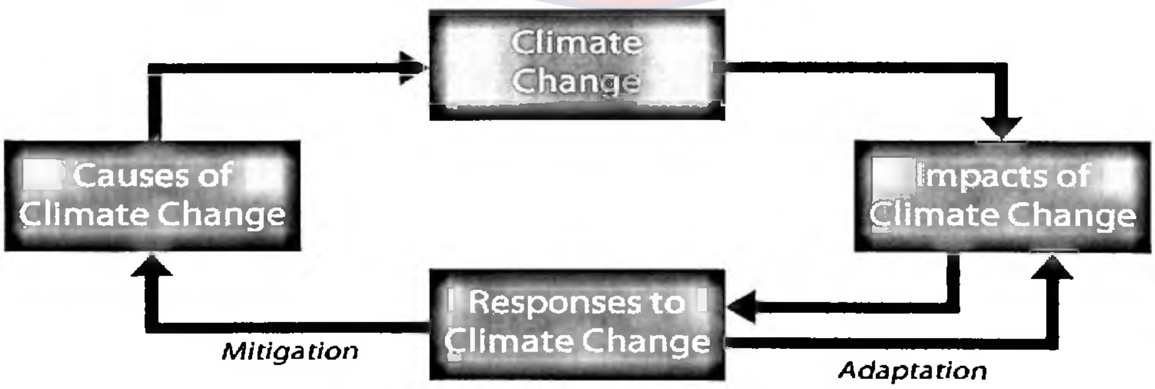

Figure 1: How people interact with the climate system.

Source: Adopted from Steffen, et al. (2018)

Several external forces influence climate system components, with radiation from the Sun being most important. Climate scientists consider the impact of human activities on the climate system as another example of external forces.

Starting on the left-hand side of Figure 1, human activities, such as tillage practices and fossil fuel burning, put heat-trapping greenhouse gases into the atmosphere, thereby changing the atmosphere's composition, increasing the greenhouse effect, and warming the near-surface layers of the atmosphere. These human activities are therefore causing climate change (top center), which has many characteristics beyond surface warming, including increased evaporation, changed rainfall quantity, intensity, and location, decreased ice and snow cover, and increased sea level among others. These climate changes have impacts on physical systems, biological systems, and human systems (right-hand side), with most of these impacts being negative. People respond to these impacts in two ways (bottom), either through mitigation or adaptation. Mitigation aims to reduce or eliminate the causes of climate change; adaptation seeks to reduce or eliminate the impacts. Together, the impacts and responses to climate change make up the total consequences of climate change.

The human dimensions of climate change shown in Figure 1 interact at all scales of the climate system and human activity. The human causes of climate change result from billions of daily local actions—such as emissions of carbon dioxide from fossil fuel combustion and forestry—that accumulate to cause a change of global climate. This global-scale change plays out differently in different regions, warming most areas while wetting some areas and drying others. These regional climate changes lead to local impacts that have more or less severity depending on the vulnerability of each place's natural and human systems. Responses vary too, with local, regional, and global efforts both to mitigate greenhouse gas emissions and adapt to climate change.

The human causes of climate change fall into two categories: proximate causes and driving forces. Proximate causes are the human activities that directly cause climate change. There are two overarching categories of proximate causes: land transformation and industrial processes. People transform the land surface in many ways, with some important types being deforestation, agriculture, urbanization, mining, reservoir building, land draining, and transportation network building. Industrial processes include energy production, transportation, manufacturing, construction, waste disposal, petrochemical, mineral, and food processing, and many other activities. All of these activities change the flux of energy and mass to the climate system.

Driving forces of climate change are complex and interactive actions that give rise to proximate causes. In other words, driving forces are the underlying reasons why people engage in various activities. There are five driving forces: population growth, technological development, economic growth, institutions, and attitudes and beliefs. Understanding the driving forces helps to answer questions such as, why do people drive cars to work (a proximate cause of climate change) when they could walk, ride a bike, or take a bus? (Steffen, et al., 2018).

Socio-cultural dimensions of climate change

The need for specific attention to the most vulnerable groups, and their role in crafting solutions and increasing resilience cannot be overemphasised. ` The goals of this transition must include fulfilment of basic needs, enjoyment of human rights, health, equity, social protection, decent work, equal participation and good governance (Prats, 2011).

The climate change that concerns the international community is anthropogenic. It thus derives from human activities and is, indeed a reflection of the ways in which human societies function and change over time. Human societies and the activities that take place within them drive climate change in different ways. Sustainable options require an understanding of the social structures that drive climate change – as a set of social problems the solutions to which are also, necessarily, social (Prats, 2011).

Smallholder farmers in Ghana are said to attribute social, religious or moral reasons for changing climate. However, commercial farmers think Western nations, mining companies, deforestation, charcoal burners, and poor government policies are the main causes of climate change (Yaro, 2013). Farmers in Northern Ghana also believed that, the lack of rain in their area is mainly due to moral transgressions such as immoral land sales, lack of obedience for the older generations, extramarital sex, lack of united action in the community, lack of respect for ancestral spirits, laziness of some farmers and alcoholism of a rainmaker (Yaro, 2013; Eguavoen, Schulz, de Wit, Weisser, & Müller-Mahn, 2013).

Academic explanations based on political perspectives are still marginalized in the major adaptation discourses, with the effect that structural causes that make people vulnerable in the first place are overlooked. Donor and government interventions, therefore, often remain technocratic, as they do not challenge and address the social factors that lead to people's vulnerability. These politically conservative approaches do not challenge the status quo, but tend to fix the deficiencies at the surface (Bassett & Fogelman, 2013; Eguavoen, Schulz, de Wit, Weisser, & Müller-Mahn, 2013).

Ecological dimensions of climate change

Forests are central to understanding and addressing many of these challenges. More than 18 percent of global carbon dioxide emissions stem from deforestation, forest degradation, and land-use change (Stern, 2006; Heltberg, Siegel, & Jorgensen, 2010). Global market demands for commodities, including bioenergy, are increasing pressure on forestlands and forest people. So are the emerging markets for forest carbon and political responses to security challenges. More than ever, the markets and politics of forests and forest people are interlinked with those of the global community (Menzies, 2007; Heltberg, Siegel, & Jorgensen, 2010). There is high risk that with climate change, attempts to use forests to mitigate climate change, and oncoming market transitions, millions of people will be pushed further into poverty and conflict; and that distinct cultures will be pushed to extinction. How tensions over forests play out in coming decades will influence the severity of climate change, the course of wars and civil conflicts, and the health of the world that our descendants will inherit (Heltberg, Siegel, & Jorgensen, 2010)

In recent years, the growth of the global economy and the growing demand for food, basic commodities, and energy have increased the pressure on forest people, who increasingly must compete for a diminishing amount of available land. Local populations are growing, resulting in increasing landlessness, migration, and local pressure for the privatization of land held in common. Climate change is affecting the ecology and ranges of the flora and fauna on which forest people depend, and undermining livelihoods. Moreover, some of the proposed approaches to reducing carbon dioxide emissions from forests threaten to criminalize traditional land use (like shifting cultivation), thus exacerbating existing tensions and eliminating local livelihoods. This new set of pressures raises the risk not only of increased poverty, social exclusion, and civil conflict among forest people; but also the risk of increased carbon dioxide emissions from continued or increased deforestation and forest degradation (Heltberg, Siegel, & Jorgensen, 2010).

Governance and political dimension of climate change

The term governance refers in many cases to the instruments or options available for arrangements to the realisation of societal aims. In addition to the state as a stakeholder in the creation, determination and implementation of these instruments in governance arrangements, civil society and/or private actors are also involved in the regulation of societal circumstances (Fröhlich & Knieling, 2013). Governance, therefore, is connected with a wide range of regulatory and non-regulatory instruments that are being proposed and initiated by non-state actors (Jordan, Wurzel, & Zito, 2007; cited in Fröhlich & Knieling, 2013). A basic distinction is made between formal and informal instruments, especially within planning sciences. Classic formal planning tools, such as land use and development plans, are opposed to informal instruments like regional conferences. Informal instruments frequently rely on communication (information, participation, cooperation) and are conducive to comprehension and mediation (Fröhlich & Knieling, 2013). The range of formal or regulative instruments includes sovereign/legal instruments, such as coordinating and integrating spatial planning, landscape planning and sectoral planning, as well as aims methods and arrangements based on laws, programmes and concepts. Economic instruments, such as taxes and subsidies, are another group of instruments that can be considered competitive (Fröhlich & Knieling, 2013).

Governance is highly contested in academia, but has been applied in a variety of contexts, including global governance, good governance, public and local governance, organizational governance, corporate governance, and knowledge governance. The arbitrary use of the term has prompted many scholars of political theory to arrive at a similar conclusion. Generally, there are three ways in which this concept is used. First, governance can be understood as a scientific concept that is employed to conceptualize and empirically trace transformations and institutionalized interventions in societies. Second, governance can be understood as a normative program based on the ambition to realize and manage political change. Third, governance also refers to a critical societal discourse, which is linked to the wider globalization debate (Fröhlich & Knieling, 2013).

Climate change is characterized by highly interrelated biophysical and social-political processes that cut across jurisdictions, administrative scales, and the boundaries of ecosystems, as well as across fields of disciplinary expertise, and thus require new political approaches (Schulz, 2011). Approaches that look at functional applications from administrative and technical perspectives seem to be on the rise. Governance, a former domain of political science, has been appropriated by other disciplines, as well as the international development community. When this concept is adjusted to a climate change adaptation context it tends to take a rather technocratic turn (Fröhlich & Knieling, 2013). Multidisciplinary studies show the importance of political circumstances on the perception of environmental change and for the creation of local vulnerability, as well as how political framework conditions determine local adaptation. In contrast, studies with a political focus observe that the socio-spatial aspects of risk and adaptation are strategically emphasized or de-emphasized by actors to legitimize their political narratives and interventions; often to serve their own interests (Fröhlich & Knieling, 2013).

How adaptation is defined and implemented across multiple scales is strongly influenced by the interests of actors in the climate change adaptation (CCA) arenas who exercise *discursive power* and are capable of dominating political negotiations, and therefore, their outcomes. Political agenda-setting is not always as transparent and straightforward as many scholars and practitioners would like it to be (Brooks, Grist, & Brown, 2009) and selective depoliticisation of the adaptation discourse can often be observed. Conceptualizing adaptation as an exclusively environmental problem, with some social challenges on the side of the affected populations that must be solved by applying quick technological and managerial fixes, meaning it turns a blind eye to the normative underpinnings of international adaptation and developmental discourse. For example, capitalist modes of production and consumption, the economic growth paradigm, corruption (as well as elite capture), and systemic governance failures are usually not denounced by the actors who benefit from the status quo (Brunnengräber, 2013; Bailey & Compston, 2012; Fröhlich & Knieling, 2013).

It is also clear that whereas recognition and clarification of land and resource rights are essential for enabling development as well as justice, legal reforms alone are insufficient to ensure that local people can protect, develop, and benefit from their assets. Rights reform in the forest sector can achieve the desired potential only with prior or concurrent action on broader governance issues that underpin the absence or weakness of rights at the local level. Such action includes attention to regulatory reform (forest regulations tend to favour the interests of large enterprises); market reform (to ensure that small producers of forest products have equal market opportunities); judicial reform (forest dwellers need a functioning judicial system and conflict resolution mechanisms to defend their rights); stronger public forest services (forest tenure reform often requires gazetting and demarcation of property boundaries, and that requires a sufficient budget and training); enforcement of laws against forest crimes (forest dwellers frequently fall victim to illegal appropriations of land and resources that are not prosecuted); and support for the emergence of small- and medium-scale forest enterprises. Engaging in these reforms can be an uphill battle because they challenge the status quo and vested interests, but measurable progress on forest tenure reform in recent years shows that such reforms are possible (Heltberg, Siegel, & Jorgensen, 2010).

Many in the development community now realize that recognizing and securing land rights, strengthening civil rights and introducing more democratic governance systems in forest areas are critical actions – not just for moral reasons, but also to achieve social, economic, and environmental goals. Fair and secure rights to natural resources, particularly land, are fundamental building blocks in any viable strategy for dealing with climate change and strengthening local and systemic resilience against future shocks. Moreover, recognizing and strengthening these rights will be key to addressing climate change mitigation and adaptation, while promoting poverty alleviation and well-being, good governance, and equitable economic growth (Heltberg, Siegel, & Jorgensen, 2010). Payments for ecosystem services, carbon trading, crop insurance schemes, and monopoly patents on climate-ready genes are symptoms of the neoliberal mantra that assumes the market is the solution to environmental problems caused by a fossilistic economy (Fröhlich & Knieling, 2013).

Causes of Climate Change

In the dominant climate change narrative, humans are an external force driving change to the earth system in a largely linear, deterministic way; the higher the forcing in terms of anthropogenic greenhouse gas emissions, the higher the global average temperature (Steffen, et al., 2018). Steffen et al. (2018) argued that, human societies and activities need to be recast as an integral, interacting component of a complex, adaptive earth system. This framing puts the focus not only on human system dynamics that reduce greenhouse gas emissions but also, on those that create or enhance negative feedbacks that reduce the risk that the earth system will cross a planetary threshold and lock into a hothouse earth pathway.

There are alarming evidences of the outcomes associated with the farming in respect to climate change. The present dominant socioeconomic system, however, is based on high-carbon economic growth and exploitative resource use (McNeill & Engelke, 2016). Attempts to modify this system have met with some success locally but little success globally in reducing greenhouse gas emissions or building more effective stewardship of the biosphere. Incremental linear changes to the present socioeconomic system are not enough to stabilize the earth system. Widespread, rapid, and fundamental transformations will likely be required to reduce the risk of crossing the threshold and locking in the hothouse earth pathway; these include changes in behaviour, technology and innovation, governance, and values (Rockström, et al., 2017; Geels, Sovacool, Schwanen, & Sorrell, 2017; O'Brien, 2018; Steffen, et al., 2018).

Steffen, et al. (2018) suggested that the earth system may be approaching a planetary threshold that could lock in a continuing rapid pathway toward much hotter conditions. This pathway would be propelled by strong, intrinsic, biogeophysical feedbacks difficult to be influence by human actions, a pathway that could not be reversed, steered, or substantially slowed. The stabilized earth trajectory requires deliberate management of humanity's relationship with the rest of the earth system if the world is to avoid crossing a planetary threshold. It is suggested that a deep transformation based on a fundamental reorientation of human values, equity, behaviour, institutions, economies, and technologies is required. Even so, the pathway toward stabilized earth will involve considerable changes to the structure and functioning of the earth system, suggesting that resilience-building strategies be given much higher priority than at present in decision making. Some signs are emerging that societies are initiating some of the necessary transformations. However, these transformations are still in initial stages, and the social/political tipping points that definitively move the current trajectory away from hothouse earth have not yet been crossed, while the door to the stabilized earth pathway may be rapidly closing (Steffen, et al., 2018).

In order to secure a healthy planet for future generations there is need for a call for action by individuals, agencies and governments worldwide. Fortunately, the United Nations is not the only organization concerned with producing constructive changes. There are other agencies and groups who help address climate change issues. Some of these agencies are governmental; others are intergovernmental or non-governmental organizations. These organizations occur locally, regionally, nationally, and internationally and can be wide-ranging or narrow in their area of focus. That said, each agency has a similar goal – to protect human society and the environment (Zolnikov, 2018).

Effects of Climate Change

While humans continue to contribute to climate change, the consequential effects of it also influence society. People, animals, and the environment similarly suffer from it. For example, stronger hurricanes and severe heat waves are not only destructive to the ecosystem by altering temperature and precipitation of the average season, but could be life-threatening (Zolnikov, 2018). Many natural and human systems feel the impacts of climate change. Natural systems experiencing climate impacts include hydrologic systems, cryospheric systems, geomorphic systems, and ecosystems. Often, natural and human systems both come under pressure from climate change at the same time and place (Steffen, et al., 2018).

Clouds, water vapour and natural greenhouse gases such as carbon dioxide (CO_2), methane, nitrous oxide and ozone are more opaque to long-wave than short-wave, trapping 80 to 90 percent of the outbound radiation from the earth's surface. This trapping influence is called the greenhouse effect. Without the greenhouse effect, the average surface temperature on earth would be -18°C instead of the 15°C observed today, and this would be too low for any sort of life. The Swedish scientist Svante Arrhenius introduced the possibility of an enhanced or man-made greenhouse effect one hundred years ago. Arrhenius hypothesized that the increased burning of coal would lead to increased concentration of carbon dioxide in the atmosphere and warms the earth (Fleming, 1998; Arrhenius, 1896 as cited in Ahene, 2003). Since Arrhenius' time, the emissions of greenhouse gases have increased dramatically. The concentration of CO_2 in the atmosphere has increased by 25 percent over pre-industrial levels (Ahene, 2003). In addition to increased burning of fossil fuels such as coal, oil and natural gas, man-made chemical substances such as Chlorofluorocarbons (CFCs) as well as methane and nitrous oxide emissions from agriculture and industry contribute to the greenhouse effect (Cline, 1992; Frankhauser, 1995).

With respect to the greenhouse effect from human activity, the IPCC noted that there has been a real, but irregular, increase of global surface temperature since the late nineteenth century amounting to 0.45°C on average (IPCC, 1996). Current emission trends will lead to a doubling of greenhouse gas concentration over pre-industrial levels around the year 2050.

Average global surface temperature has increased by approximately 0.6°C since the late 19th century, with 95 percent confidence that it lies between 0.4 and 0.8°C (IPCC, 1996). Most of this increase has occurred in two periods, from about 1910 to 1945 and since 1976; the largest warming in recent period has been recorded in the winter extra-tropical Northern Hemisphere (IPCC, 1990; 1996). The warming rate of 0.17°C per decade since 1976 has been slightly larger than the rate of warming during the 1910 to 1945 period (specifically, 0.14°C per decade), although the total increase in temperature is larger for the 1910 to 1945 period (IPCC, 1990). The most recent periods of warming also recorded a faster rate of warming over land compared with the oceans (IPCC, 1990; 1996).

According to the IPCC Third Assessment Report (Scientist Assessment), warming from 1910 to 1945 was initially concentrated in the North Atlantic and nearby regions. During 1946 to 1975, the Southern Hemisphere was warm whilst the Northern Hemisphere showed cooling. Temperature trends in the Twentieth Century exhibit a broad pattern of tropical warming with extra-tropical trends being more variable. The El-Nino event in 1997/1998 is associated with the high global temperature in both surface and tropospheric temperature. Warming was emphasized in the Northern Hemisphere in winter and spring with all year-round cooling in the Southern Hemisphere oceans and the Antarctica between 1976 and 2000 (IPCC, 2001). The North Atlantic/Arctic Oscillation Westerly phase and the Pacific variability are recognised to have caused global temperature change since the 1970s (Ahene, 2003).

The impacts of climate change can be positive or negative in the same systems and in the same places. For instance, considering the natural and human systems found in areas with cold winters and considerable ice and snow, a positive impact of climate change is the reduction in auto accidents resulting from decreasing ice and snow on roadways during winter. A negative impact is the shrinking of water supplies caused by reduced snow packs and glaciers (Steffen, et al., 2018).

Individual farmers feel the impacts of climate change both directly and indirectly. The direct impacts for farmers occur when the impact of climate change itself causes them harm (or benefit, but unfortunately most impacts are negative). Indirect impacts for farmers occur when the impact of climate change has an effect on some system that humans rely on or engage with. So the impact is not happening directly to people, instead, it must be seen as setting of a chain off dominoes of consequences that eventually affect humans.

There are many other ways that climate change affects people and the things they value. We know, for instance, that climate change is increasing the frequencies and intensities of heavy downpours. We also know that climate change is increasing variation in rainfall from year to year. For agriculture, the result of more frequent, more intense downpours is localized crop loss from damage to plants and agricultural infrastructure. Increasing variation in wet and dry years means that, without irrigation, there are greater year-to-year variations in agricultural yields. These findings suggest that the impacts of climate change will create winners and losers in agriculture. All other things being equal, farmers lose when yields decrease because heavy downpours flatten their crops or droughts ravage the countryside. On the contrary, farmers win when the localized downpours miss their fields and strike the fields of their competitors. They also win when yields go up because of a moist year.

One very recognisable feature of rainfall in Ghana is its seasonal character and very high year to year variability. Rainfall in Ghana rarely prolongs for more than 3 hours in all parts of the country. In the dry months, rainfall duration would not reach 10 hours in a month and even in the wet seasons, the average total duration of rain is only about 30 to 40 hours in a month. Temperatures in Ghana are generally high, with little variation from year to year. Annual mean temperatures also show only small variations across the country. From 1961 to 1990, temperature rise of about 1and reductions in rainfall of approximately 20% were recorded in Ghana (EPA, 2000).

A 2°C rise in temperature is very significant because even if a 1°C rise in temperature is attained by 2100 above current mean temperatures, it would be larger than any century time-scale trend for the past 10,000 years. Mean annual rainfall is projected to decrease by 170 mm in the Sudan Savanna Zone, 74 mm in the Guinea Savanna Zone and 99 mm in the Semi-Deciduous Rainforest Zone, respectively by the year 2100. The only exception to these rainfall decreases was observed in the High Rainforest Zone where the mean annual rainfall is projected to increase by 1105mm by the year 2100. The predicted trend in rainfall in all regions is similar to the observed trend during the baseline period. However, the observed rate of decrease in rainfall of about 5.4% per decade between 1961 and 1990 is larger than the average predicted rate of decrease of about 4% per decade between 2000 and 2100, due to the projected increases in the high rainforest. Projected changes in rainfall are also subject to uncertainty mainly due to the uncertainty in the way the atmosphere will respond to increased concentrations of greenhouse gases (Gyampoh, 2009; Obeng, Nutakor, Dumenu, Samar, & Owusu-Sekyere, 2011; Dumenu & Obeng, 2016).

As posited by other authors, agriculture is a significant contributor to greenhouse gas emissions, and it is also vulnerable to changing weather patterns, diseases and pests expected to result from climate change (IPCC, 2007; Walthall et al., 2012; Mase, Gramig, & Prokopy, 2017). The scientific evidence has shown that climate change is a global challenge facing humans and their socio-economic activities, health, livelihood, and food security (Romieu et al., 2010; Amjath-Babu et al., 2016; Clarke et al., 2012). Rural farmers in Sub-Saharan Africa are likely to be more vulnerable to climate change, particularly because of compounding challenges of poverty, low infrastructural and technological development, and high dependence on rain-fed agriculture (Ericksen et al., 2011; Lipper et al., 2014; Nelson et al., 2014; Adimassu and Kessler, 2016).

Warming of the ocean surface above average was severe in 2015 and 2016. As reported by FAO (2017a), El Niño within these two years is one of the intense and widespread in the past 100 years, and this has impact on crops and livestock production and livelihoods. The agriculture, food security and nutritional status of tens of millions of people in Africa are currently affected by El Niño related droughts and floods. In early July 2016, FAO estimated that more than 60 million people faced food shortages because of El Niño-related droughts. The expected effects of climate change, including higher temperatures, extreme weather events, drought, rising sea levels, disruption of ecosystems and loss of biodiversity, will seriously affect agriculture and rural livelihoods if no action is taken to improve adaptation and mitigation capacity at local, country and regional levels (FAO, 2017a).

Vulnerability to Climate Impacts

Vulnerability refers to the degree to which people or the things they value are susceptible to, or are unable to cope with, the adverse impacts of climate change. Thus, vulnerability determines how severe the impacts of climate change might be.

There are three dimensions of vulnerability to climate change: exposure, sensitivity, and adaptive capacity. Exposure is the degree to which people and the things they value could be exposed to climate variation or change; sensitivity is the degree to which they could be harmed by that exposure; and adaptive capacity is the degree to which they could mitigate the potential for harm by taking action to reduce exposure or sensitivity (Steffen, et al., 2018). Starting with exposure, vulnerability of a system depends partly on the frequency and intensity of drought, on the number of people and their location, and on the type and safe yield of the water supply. Sensitivity of the system to drought is a function of the age and income of the population, of the size of the distribution network and the age of infrastructure, and of how the water supply responds to dry conditions (that is, whether it decreases precipitously or not at all when precipitation stops). The system's ability to adapt to drought—its adaptive capacity—is determined, among other factors, by its access to technology, information, and money, and by how well it is managed. Hence, a system exposed to an intense drought and having a sensitive water supply, an infrastructure consisting of rotting wooden pipes, and limited access to resources and information would be quite vulnerable. In contrast, another system exposed to the same drought but having an insensitive water supply, modern infrastructure, and good access to resources and information would be much less vulnerable (Steffen, et al., 2018).

The expression "things they value" not only refers to economic value and wealth, but also to places and to cultural, spiritual, and personal values. In addition, this expression refers to critical physical and social infrastructure, including such physical infrastructure as police, emergency, and health services buildings, communication and transportation networks, public utilities, and schools and daycare centers, and such social infrastructure as extended families, neighborhood watch groups, fraternal organizations, and more. The expression even refers to such factors as economic growth rates and economic vitality. People value some places and things for intrinsic reasons and some because they need them to function successfully in our society (Steffen, et al., 2018).

Some people and the things they value can be highly vulnerable to low-impact climate changes because of high sensitivity or low adaptive capacity, while others can have little vulnerability to even high-impact climate changes because of insensitivity or high adaptive capacity. Climate change will result in highly variable impact patterns because of these variations in vulnerability in time and space (Steffen, et al., 2018).

Some groups of people are inherently more vulnerable to climate change than others. The very old or very young, the sick, and the physically or mentally challenged are vulnerable. Disadvantaged groups, such as minorities, those with few educational opportunities, or non-English speakers are more vulnerable than the majority, better-educated, English-speaking population. Women, who typically spend more time and effort on care-giving to parents, children, and the sick than men do, are more vulnerable because that care-giving exposes them more to the impacts of climate change. More vulnerable groups often combine these categories, such as the poor—who can be old, minority, non-English speaking, and female, for example. Another example of a particularly vulnerable group is the single-mother household, which can be headed by a poor woman of color who is responsible not only for caregiving, but also for providing the family income (Steffen, et al., 2018).

Impacts of Climate Change on Food Security

The impacts of climate change on food security depend on changes in the seasonal timing of temperature and water availability, changes in CO_2 concentrations, and changes in the prevalence of pests and diseases and their effects on crop productivity (Arnell, 2006). Agriculture, especially crop production, has a long history of its fair share of negative climatic impacts. Ranganathan (1949) observed that the Chota Nagpur region in India used to receive fairly frequent afternoon showers known as instability rain during summer which favoured tea plantations but a significant reduction in these instability rains has led to a disappearance of the tea gardens. This signifies a reduction in the food availability to the Chota Nagpor region. The greatest reductions in food productivity is expected in the equatorial and tropical regions where crop growth is usually rain-dependent and temperature-limited (Arnell, 2006), as is currently being experienced in Africa (IPCC, 2001). Increased heat stress during extreme events can also reduce productivity in temperate regions, and effects of pests and disease depend on local climatic limits (Arnell, 2006).

Other studies (e.g. Parry et al., 2004) argue that since gradual climate change would result in a general shift in world food production to higher latitudes, increases in production of cereals in developed countries could possibly compensate for reductions in developing countries but all scenarios developed indicate that crop prices would rise, leading to an increase in risk of hunger, particularly in Africa. Accelerated climate change would exaggerate this pattern, leading to greater increases in food prices (Arnell, 2006). Warming temperatures may also negatively affect fisheries production (Roessig et. al., 2004 cited in Gyampoh, 2009).

Climate change resulting from greenhouse gas emissions and land use changes is generally projected to exacerbate the current and emerging problems with food security for many developing countries (Vermeulen, Campbell, & Ingram, 2012). This is due to the expected negative effects of warming on agricultural production in tropical and subtropical regions, where yields are predicted to decrease due to excessively high temperatures and increased drought risks and higher frequency of extreme climatic events causing yield losses. In Sub-Saharan Africa, climate change is generally projected to cause considerable yield losses in most agricultural crops (Schlenker & Lobell, 2010). Therefore, adaptations to climate change in agriculture is particularly challenging in developing countries, but also extremely important (Mertz et al., 2001 cited in Mawunya & Adiku, 2013).

In Ghana, Tilman, Cassman, Matson, Naylor, & Polasky (2002) observed that, even with a stabilisation of CO_2, maize yields will still decrease by 2.5 to 5 percent by the 2080s. Owusu, Abdulai, & Abdul-Rahman (2011) observed that rainfall in both Ejura and Wenchi (transition zone) has seen a reduction in both the major and minor rainy seasons and an infilling during the short dry spell resulting in a high risk of crop failure during the minor rainy season as the onset of the rain delays and early termination occurs. Along the coast, marine resources dependent and inland communities have been studied.

Climate change has a lot of impact on human environments beyond food security. Increase in global mean temperature and changes in rainfall is likely to be the most hydrologically important among the various effects of climate change (Linhares, 2007). The impacts of climate change on water resources are closely linked with changes in land cover and land use and have on some occasions been difficult to isolate. This is so because human-induced land cover and land use changes constitute a major source of anthropogenic influence that can independently cause both significant hydrological and climate changes through its direct effects on the hydrological cycle and greenhouse gas emission respectively. Reduction in water availability has been linked to thermocline circulation collapse and accelerated climate change. It must be noted that both thermohaline circulation collapse and accelerated climate change not only alter the annual volume of runoff, but in large regions change the timing of streamflow through the year – and this change in timing can have very significant impacts on resource availability and reliability (Arnell, 2006 cited in Mawunya & Adiku, 2013).

In Africa, warm sea surface temperatures may lead to increased droughts in equatorial and subtropical Eastern Africa (Funk et al., 2005). Less precipitation during already dry months can lead to drought and increased desertification (IPCC, 2001b). Some major rivers will be highly affected by climate reductions. From Arnell (2006), accelerated climate change will increase the numbers of people with an increase in water resource-stressed by 2055 from around 1 billion to approximately 1.3 billion, with most of the increase occurring in Europe, North and Central America, and West Africa. Although the effects are not expected to be the same across the globe, accelerated climate change is expected to have relatively little effect on the numbers of people with an apparent decrease in water resources stress in the High Rainforest Zone (Gyampoh, 2009).

Meeting the food needs of families in Sub-Saharan Africa remains a serious challenge. Most often, this challenge arises due to widespread poverty and conflict (Misselhorn, 2005; Oldewage-Theron et al., 2006); drought, famine and other negative weather patterns exacerbated by global climate change (Rosenzweig et al., 2001); degradation and deforestation (Baro & Deubel, 2006), increased food prices due to the growth in demand for biofuels (Trostle, 2008) and low agricultural productivity (Haile, 2005). Combination of these factors restricts access to food for many in developing countries.

Ghana has been fairly stable in terms of food security on national basis, although, some pockets of food insecurities situations have been recorded in some areas particularly in the three northern regions. Africa has witnessed severe droughts in 1970, 1983 and 1984 in the past four decades where between 24 to 30 countries were affected. However, the 1983 and 1984 droughts were the most severe causing wide spread famine in Africa requiring massive humanitarian food aid (Haile, 2005).

Ghana was hardly affected by 1983 drought where acute food shortage was recorded and this saw people depending on all kinds of material for survival. Among the food consumed during this period includes cocoyam comb, rhizome of bamboo, water leafs and unripe bananas were substituted for plantain which under normal circumstances were not part of Ghanaian foodstuff. According to Ghana Statistical Service (2008), about 18.2 percent of Ghanaians who fall below the extreme poverty line are chronically food insecure. Also about 10.3 percent of those above the extreme poverty line but classified as poor are vulnerable to food insecurity depending on the whims of the weather (MOFA, 2010). However, most of the food security situations in Ghana are more cyclical in nature and are recorded in all the ten regions but Upper East Region, for example is the most vulnerable to transient food insecurity.

Climate change is a major factor redefining the world food equation and having an enormous impact on the food security of poor people. This phenomenon is a ticking time bomb waiting to explode. It is now not only a better-understood scientific fact, but also a phenomenon, which is already affecting global temperatures, regional weather patterns and physico-biological systems. Attributed directly or indirectly to human activity, climate change puts additional pressure on already over-exploited natural resources. It negatively affects crop yields, stability of food supplies and the ability of people to access and utilize food in many parts of the developing world (Dan-Azumi, 2011).

Although rich countries are responsible for most greenhouse gas emissions, with a growing contribution of emerging economies (such as China, India and Brazil), the impact of climate change is expected to be most severe in developing countries and on poor people. The higher vulnerability of the poor is not only due to geography, but also to limited adaptive and capacities. Since low-income communities depend directly on agriculture, forestry, fisheries, aquaculture and climate sensitive resources, climate change impacts will adversely affect food supply in the future. While technological advances in agriculture have led to increases in food production, the food production system is still highly dependent on climate and weather conditions. Any slight change in climate can have drastic effects on agricultural production (Dan-Azumi, 2011).

The effects of climate change are expected to be heterogeneous and region-specific. Some positive effects of climate change such as CO_2 fertilization of plants could contribute to increasing food production and security. However, impacts – such as rising temperatures and increased frequency of extreme weather events – will put severe pressure on farming, hence food availability, stability, access and utilisation. Climate change could lead to increased water stress, decreased biodiversity, damaged ecosystems, rising sea levels and, potentially, to social conflicts due to increased competition over limited natural resources. Smallholder agriculture, pastoralist, forestry, fisheries and aquaculture are among the systems most at risk (Dan-Azumi, 2011).

Climate Change Response

The key to reducing the impacts of and vulnerabilities to climate change depends on appropriate strategies employed to deal with the deleterious effects experienced from the climate change. Humans can respond to climate change impacts in two ways. First, they can address the causes of climate change through mitigation. Mitigation involves actions that prevent, limit, delay, or slow the rate of climate change. Mitigation can involve direct interventions in the natural environment, direct interventions in the proximate causes, or indirect interventions through the driving forces. An example of mitigation would be government policies aimed at reducing the number of cars on the road and, consequently, the carbon dioxide emissions from tail pipes (Steffen, et al., 2018).

Current policy responses to climate change threats – particularly those affecting agriculture, and hence the majority of the rural poor – still underestimate the gravity of the situation. In agriculture, climate change adaptation can go hand-in-hand with mitigation, and appropriate measures need to be integrated into the overall development approaches and agenda (Butt, McCarl, Angerer, Dyke, & Stuth, 2005). Although a considerable body of work has studied and projected the adverse consequences of climate change, research on how the negative effects for developing countries and food insecure people could be mitigated is still very limited. If the global community does not invest massively to tackle the climate change challenges, the social and economic costs will be disastrous (Dan-Azumi, 2011).

Several opportunities exist that allow us to counteract climate change outcomes. By reducing carbon dioxide and methane emissions, approximately 2.4 million premature deaths per year would be avoided (United Nations Environment Programme, 2011; Woodward, 2014; Zolnikov, 2018).

Adaptation and mitigation are collective efforts by individuals, groups and government used to manage the risks of climate change (IPCC, 2014) (Adger, Arnell, & Tompkins, 2005). These strategies can be supported by policies to help stabilize atmospheric conditions and can be shaped by evaluating expected risks and benefits, understanding the role of government and policy, upholding ethical and cultural standards, and recognizing responses to risk and uncertainty (IPCC, 2014). However, these ideas and solutions need to work in tandem with each other; effective change depends on government, policy, industry, and population support to work together to improve upon and implement adaptation and mitigation objectives (IPCC, 2014). These integrated responses can be applied all the way from large-scale corporations to each individual person. Enabling factors could occur through effective institution and governance, innovative investment in environmental-focused technology and infrastructure, and changed livelihoods, behaviour, and lifestyle choices. Institutions and government could improve city infrastructure, create early warning systems for disaster risk management, maintain wetlands and urban green spaces, integrate coastal zone management, and have incentives for building standards and practices (IPCC, 2014; Zolnikov, 2018).

There are limits to adaptation, which revolve around thresholds of ecological, economic, or technological nature (Adger, et al., 2009). For instance, ecological or physical thresholds exist beyond which adaptation responses will be unable to prevent serious climate change impacts (e.g. temperature thresholds for organisms, such as thermal stress in corals or cold- water fishes). Economic thresholds can be defined as when the costs of adaptation exceed the costs of averted impacts (ie it is more expensive to adapt than to experience the impacts). Finally, there are technological thresholds beyond which engineered or management solutions cannot avert the effects of climate change. The rate, magnitude, and character of climatic changes will influence whether and when these limits are exceeded (Stein, et al., 2013).

Environmental technology could include less polluting and more resource-efficient products or practices, such as green or clean technology (e.g. wind or solar power). Collectively, individual practices range from everyday actions, like using less water to taking public transportation. Another personal change could be to eat less meat, as meat consumption not only contributes to deforestation through cattle ranching demands, but also uses more water for growth and maintenance (Zolnikov, 2018).
Climate adaptation focuses primarily on both active and passive responses to climate change by humans. As distinct from use of the term "adaptation" in the traditional evolutionary biology sense, this focuses on genetic changes over time in response to selective pressures. Because adaptation is fundamentally about managing change, it can best be thought of as a continuing process rather than as a fixed endpoint (Stein, et al., 2013).

It is important to note that adaptation and mitigation operate on many different special and social scales and that the degree of success depends on distribution and the capacity to adapt, which will inevitably vary over time. Thus, sustainability of adaption to climate change is another key factor that will be used to alter current greenhouse gas emissions (Adger, Arnell, & Tompkins, 2005) (Zolnikov, 2018). This ultimately requires large-scale investment in markets, such as coastal planning, the built environment, water resources, and resource-based livelihoods (Adger, Arnell, & Tompkins, 2005) (Zolnikov, 2018). Mitigation and adaptation efforts do not have to deter the economy; in fact, economic development can be simulated while curbing harmful emissions (Woodward, 2014). Policies could focus on climate reduction techniques while supporting employment, social development, and wellness (Woodward, 2014; The Global Commission on the Economy and Climate, 2014).

Adaptive Capacity and Climate Change

While accepting that the impact of climate change is widespread and farmers' perception is not unclear, some studies have observed that some farmers who have observed climate change fail to respond (Davis, 1996; Maddison, 2006). Maddison (2006) listed inability to borrow, lack of appropriate seed, security of land tenure or market accessibility as barriers. He further observed that although it is the experienced farmer who perceives climate change, it is mostly the educated farmer that responds. The implication is that the capacity to adapt is variable. Adaptive capacity here refers to "the ability of a (human) system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (FAO, 2008). Low adaptive capacity has been attributed to deteriorating ecological base, widespread poverty, inequitable land distribution, and a high dependence on the natural resource base (Hulme, 1996; IPCC, 1998; Magadza, 2003; Ikeme, 2003).

Access, status, and ability are key factors in adaptive capacity. 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. It is usually people's few productive assets that are at greatest risk from the impacts of climate change. Physical assets can be damaged or destroyed, financial losses can be incurred, natural assets can be degraded and social assets can be undermined. Improving adaptive capacity is important in order to reduce vulnerability to climate change (Bradshaw et al., 2004 cited in Egyir et al., 2015).

Smit et al., (2000) see adaptation simply as a response to concerns about climate change. They assert that adaptation depends fundamentally on the characteristics of the system of interest including its sensitivities and vulnerabilities. Vulnerability means not lack or want but defencelessness (Chambers, 1989). It includes insecurity, exposure to risk, shocks and stress; exposure to contingencies and difficulties in coping with them. The nature of adaptation process and forms can be distinguished by attributes such as timing, purposefulness and effect. Adaptation to climate change has been viewed by others as a long term phenomenon in that when farmers using traditional techniques of agricultural production notice that the climate has altered, they need time to identify potentially useful adaptations, learn, organize resource and implement them (Maddison, 2006; Smit & Wandel, 2006). The resources include those from farmer' own sources and those external to them; the latter include policy making and scientific knowledge systems (Yaro, 2004). Scientific knowledge systems encompass the use of new varieties of crops and breeds of animals, integrated pest management principles, integrated soil fertility management principles and forestry management. Both coping and adaptation strategies concern diversification and specialization which have been observed as farm level response to climate change (Bradshaw et al., 2004).

Denton et al., (2002) observed that much has been invested in Africa in terms of capacity building, but more is needed to enhance the adaptive capacity of institutions, organizations and individuals. Bryan et al., (2013) conducted a study based on farm household and Participatory Rural Appraisal data collected from districts in various agro-ecological zones in Kenya. The paper examines farmers' perceptions of climate change, ongoing adaptation measures, and factors influencing farmers' decisions to adapt. The results showed that households face considerable challenges in adapting to climate change. While many households have made small adjustments to their farming practices in response to climate change (in particular, changing planting decisions), few households are able to make more costly investments, for example in agroforestry or irrigation, although there is a desire to invest in such measures. This emphasizes the need for greater investments in rural and agricultural development to support the ability of households to make strategic, long-term decisions that affect their future wellbeing.

Concepts of Food security

After the World Food Conference in 1974, the term "food security" gained a lot of attention and attracted so many definitions from various organizations and individual researchers. For instance, World Bank (1986), defined food security as "access by all people at all times to enough food for an active and healthy life." This definition provides the basis for many definitions and conceptual models.

FAO (1996) defined food security to include the nutritional value and food preferences. It argued that food security is a situation when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life. Similarly, Pinstrup-Andersen, (2009) describe national food as whether a country had access to enough food to meet dietary energy requirements of her citizens. To some it connotes self-sufficiency, which means a country produces enough food to meet its population's demand. But broadly, national food security measures the extent to which a country has the means to make available to its people the food needed or demanded, irrespective of whether the food is domestically produced or imported (Maxwell & Smith, 1992).

The literature on food security has also expanded considerably over the years. Likewise, policy statements and corresponding agency guidelines have been developed by numerous international organizations (Maxwell & Smith, 1992). According to Bokeloh et al. (2009), food insecurity is the absence of food security and applies to a wide range of phenomena ranging from famine to periodic hunger to uncertain food supply (Kuwornu et al., 2013). Maharjan and Khatri-Chhetri (2006) established that food insecurity is the inability of a household or individuals to meet their daily required food consumption levels in the face of fluctuating production, food price and income.

Other definitions include "the ability to assure, on a long term basis, that the food system provides the total population access to a timely, reliable and nutritionally adequate supply of food" (Staatz, 1990). "Food insecurity exists when members of a household have an inadequate diet for part or all of the year or face the possibility of an inadequate diet in the future" (Phillips & Taylor, 1990). "The viability of the household as a productive and reproductive unit threatened by food shortage" (Frankenberger, 1992).

Definitions of Food Security

Jones et al. (2013) pointed out that the definition of food security is still an evolving concept dating far back as the beginning of the post-World War I. Following the World War II, the international community began to collect national food balance sheet data to facilitate food allocation and distribution efforts in conflict-affected regions (FAO, 2001). This choice of metric implicitly give precedence to the availability of food supplies as the primary consideration for determining an economy's food security. In the early 1970s, food security emerged as a concept of food supply; the food crisis during that period led to concerns that global food supply shortages would threaten political stability (Simmons & Saundry, 2012). Although food availability remains as one of the three fundamental components of current understanding of food security, scholars at the time soon began to recognize that food availability was not sufficient for ensuring household access to food (Jones et al., 2013).

Sen (1981) brought to the forefront the importance of food access in determining food security by underscoring historical paradigms of famine circumstances in countries with sufficient national food supplies. He contended that the poor may lack privileges to food under conditions of high food prices and low demand for wage labour, even if food supplies are sufficient. Given that the poor spend a large proportion of their household income on food and depend on their labour power as their primary asset, such conditions inhibit their access to available food. Emblematic of this shift in thinking, the definition of food security adopted at the 1974 World Food Summit that underscored ensuring "availability at all times of adequate world food supplies" (United Nations, 1975), was revised in 1983 to reflect this idea of entitlements by stating that food security also required "physical and economic access to basic food" (FAO, 1983).

The definition of food security continued to evolve as concerns emerged over inequitable distribution and access to food not only within countries, but within households (Jones et al., 2013). For example, analyses of data on intra-household behaviour suggested that expenditure allocations by women compared with men favoured investments in the health, nutrition, and education of children in the household and that parents do not always have identical preferences toward male and female children (Kennedy & Cogill, 1987, Hoddinott & Haddad, 1994; Quisumbing & Maluccio, 1999). Therefore, the food acquisition behaviours of households are important for translating physical and economic access to food into food security (Jones et al., 2013). By the mid-1990s, alleviating micronutrient undernutrition, particularly deficiencies in iron, vitamin A, and iodine, became the primary focus of nutrition research (Jonsson, 2010), thereby shifting attention from mere caloric sufficiency to overall diet quality. Both of these trends had implications for the conceptualization of household food security (Jones et al., 2013).

Specifically, "utilisation" is considered as a third component, or domain of food security, in recognition that physical and economic access to food and food acquisition are necessary, but insufficient, for ensuring food security within households. Utilisation reflects differences in the allocation of food within households, the nutritional quality of that food, and variation in the extent to which the nutrients in food are able to be absorbed and metabolized by individuals within households (e.g., because of differences in health status or the bioavailability of micronutrients). Thus, delegates at the 1996 World Food Summit adopted a further revised definition of food security that clearly highlighted the importance of diet quality as well as individual, and not just household, dietary needs (Jones et al., 2013).

The 1996 FAO definition of food security is widely used today. It incorporates not only the 3 domains of food security discussed above, availability, access, and utilisation, but also the idea that the ability to acquire socially and culturally acceptable foods and to do so in acceptable ways is important. These conditions may be seen as necessary for ensuring adequate food access. The phrase "at all times" also highlights a fourth and less commonly recognized component of food security, i.e., stability of food security over time. Food security often varies across time, whether seasonally or as a result of irregular shocks such as weather events, deaths, or regional conflicts (Barrett , 2010). Food insecurity, then, may be chronic or transitory (Jones et al., 2013). This definition suggests that food insecurity is the absence of one or more of these conditions. Food insecurity is sometimes classified as chronic or transitory, with seasonal food insecurity falling between the two types (FAO, 2008).

The two conditions are in fact interconnected and households may experience both at different times. For example, successive exposure to temporary, less severe shocks may precipitate the sale of assets, investment in agricultural production on marginal land, or seeking hazardous or unreliable employment. These coping strategies may then lead to more severe shocks, failed returns on investments, and an eventual fall into a state of chronic food insecurity (Maxwell & Smith, 1992; Carter & Barrett, 2006, cited in Jones et al., 2013). The concept of food security covers not only the amount of food required to guarantee the absence of hunger, but also the right choice of nutritional intake to avoid malnutrition and health issues (Barrett C. B., Food security and food assistance programs., 2002). Although food insecurity can arise due to shocks at the national level, putting entire populations in danger, it occurs at an individual level as a result of idiosyncratic shocks as well (Dethier & Effenberger, 2012).

Some important modifications were made to the core concepts of food security. The first is of such modification is the "quality of entitlement." Thus, the highest state of food security requires not just secure and stable access to a sufficient quantity of food, but also access to food that is nutritionally of adequate quality, culturally acceptable, procured without any loss of dignity and self-determination, and consistent with the realisation of other basic needs. This transforms food security from a uni-dimensional to a multi-dimensional objective and immediately raises problems of measurement. The inclusion of "safe and nutritious" stresses food safety and nutritional composition whiles the addition of food preferences" changes the concept of food security from mere access to enough food, to access to the food preferred.

When an individual or population lacks, or is potentially vulnerable due to the absence of, one or more factors outlined in the above definition, then it suffers from, or is at risk of becoming food insecure. The inclusion of stability of food supply, and food and nutrition safety in the definition of food security (MoFA, 2007) has added additional dimensions to food security. Also, the inclusion of "safe and nutritious" stresses food safety and nutritional composition whiles the addition of food preferences" by the World Bank changes the concept of food security from mere access to enough food, to access to the food preferred.

Further, the definition of food security captures undernutrition. Thus it has to do with influences of poor absorption and/or poor biological use of nutrients consumed. The most convenient assumption for an agricultural economic analysis would be to abstract from these influences. The balance between quantity and quality is also key in the modifying the definition of food security in recent times. However, this balance cannot be decided without reference to food insecure people themselves, and the second modification is precisely to give greater weight in definitions of household food security to the perceptions of the food insecure. In this view, food insecurity is not an objectively defined level of access to food or quality thereof, but rather the level or quality that people perceive to be inadequate (Loevinsohn & Gillespie, 2003).

Jradet et al. (2010), further elabourated on five dimensions of food security as food availability, food accessibility, food utilisation, stability of food supply and food and nutrition safety. Food availability refers to the physical presence of food which may come from own production, purchases from internal market or import from overseas. Gregory et al. (2005) explained that food availability refers to the existence of food stocks for consumption. Food Access is the ability to obtain sufficient food of guaranteed quality and quantity to meet nutritional requirements of all household members. Here, the food should be at right place at the right time and people should have economic freedom or purchasing power to buy adequate and nutritious food. Kuwornu et al., (2013), explained that food access is determined by physical and financial resources, as well as by social and political factors. Food utilisation refers to ingestion and digestion of adequate and quality food for maintenance of good health. This means proper biological use of food, requiring a diet that contains sufficient energy and essential nutrients, as well as knowledge of food storage, processing, basic nutrition and childcare and illness management.

Stability of food Supply refers to the continuous supply of adequate food all year round without shortages. In the mist of growing population, unfavourable climatic patterns and growing demand for biofuel use, constant supply of food will depend on improved productivity and availability of proper storage facilities. Means of distribution of food required improvement through provision of motorable roads to food growing areas. The use of storage van here will be a key element to prevent post-harvest losses to sustain the interest of farmers to grow more to feed the population.

Food and nutrition safety is part of a wide range of issues which go beyond the avoidance of food-borne biological pathogens, chemical toxicants, and other hazards (FAO, 2002). There is growing concern of consumers of developed countries about the effects of the food they eat on their health. Consumers expect food not only to meet their nutritional needs but also should be wholesome and tasty, and to be produced ethically respecting the environment, animal health and welfare. This, however, is not a priority in most developing countries where the major concerns are access and availability of a nutritious diet throughout the year at relatively low costs (FAO, 2002). Developing countries are forced to overlook food safety due to high poverty and illiteracy rate. However, the operational definition for food security by Ministry of Food and Agriculture in Ghana is “good quality nutritious food hygienically packaged, attractively presented, available in sufficient quantities all year round and located at the right place at affordable prices” (MoFA, 2007).

Dimensions of Food Security

Food security is the outcome of food system operating efficiently. Efficient food system contributes positively to all dimensions of food security. Following are the dimensions of food security.

Food availability

The concept of "enough food" is presented in different ways in literature. Kracht (1981) refers to food sufficiency as enough food for life, health and growth of the young and for productive effort. Reutlinger, Knapp, Yaron, Tapiero, et al. (1980), define food sufficiency as a minimal level of food consumption. World Bank (1986) described enough food as the basic food needed for an active healthy life. FAO (1983) referred to food sufficiency as the food adequate to meet nutritional needs. According to Barraclough and Utting (1987) and Sahn (1989), sufficiency of food is enough food to supply the energy needed for all family members to live healthy, active and productive lives.

Availability refers to the physical existence of food. It addresses supply side of the food security and expects sufficient quantities of quality food from domestic agriculture production or import. At the national level, food availability is a combination of domestic food production, commercial food imports and exports, food aid and domestic food stocks. This is simple mathematical calculation whether the food available in certain locality or country is enough to feed the total population in that particular territory and calculated from the level of local agriculture production in that territory, stock levels and net import or export (Bajagai, 2010).

At the household level, food could be from own production or bought from the local market. Regarding food production, water resources are required to produce the crops. This dimension of food security at different levels can be assessed by precipitation record, food balance sheet, food market survey, agricultural production planet. Similarly, indicators of food security for this dimension at different levels are fertility rate, food production, population flows, harvesting time, staple food production, food storage, and consumption of wild foods among others. The amount of available protein per person per day increased by 13 percent at the world level between 1990–1992 and 2007–2009. However, Africa still ranks lowest in this indicator compared with other regions (FAO, IFAD & WFP, 2015).

Food access

Household food access is the ability to obtain sufficient food of guaranteed quality and quantity to meet nutritional requirements of all household members (Kuwornu, Suleyman, & Amegashie, 2013). Thus, the food should always be available at right place, at the right time and people should have economic freedom or purchasing power to buy adequate and nutritious food.

It is often argued that the focus on access to food is a phenomenon of the 1980s, largely resulting from the pioneering work of (Sen, 1981) on food entitlements. However, the interest in whether and how people acquire food has a longer pedigree and is rooted in nutrition planning (Maxwell & Smith, 1992). Food prices play an important role for the poor because approximately three-quarters of their income is spent on staple foods. Food price increases have a major impact on poor consumers and are a threat to their food security (Dethier & Effenberger, 2012).

Having sufficient food at national level or at certain territory cannot be taken as the proof that all the household or individuals in that territory have enough food to eat. Food access is another dimension of food security which encompasses income, expenditure and buying capacity of households or individuals. Food access addresses whether the households or individuals have enough resources to acquire appropriate quantity of quality foods. Access is ensured when all households have enough resources to obtain food in sufficient quantity, quality and diversity for a nutritious diet. This depends mainly on the amount of household resources and on prices. In addition, accessibility is also a question of the physical, social and policy environment. Drastic changes in these dimensions may seriously disrupt production strategies and threaten food access of affected households (Bajagai, 2010).

Some of the indicators of this dimension at different levels are food price, wage rate, per capita food consumption, meal frequency, employment rate etc. and the dimension can be assessed by Vulnerability Analysis and mapping (VAM), Food Access Survey, Food Focus Group Discussion, Intra- household food frequency questionnaire, among others. Interventions to improve this dimension of food security are inter alia on-farm, off-farm and non-farm employment creation, school-feeding program and breast-feeding campaign (Bajagai, 2010).

Food utilization

Food utilization is another dimension of food security that addresses not only how much food the people eat but also what and how they eat. It also covers the food preparation, intra-household food distribution, water and sanitation and health care practices. The nutritional outcome of the food eaten by an individual will be appropriate and optimum only when food is prepared or cooked properly, there is adequate diversity of the diet and proper feeding and caring practices are practised (Bajagai, 2010).

The concept 'use' refers to the socio-economic aspects of household food and nutrition security, determined by knowledge and habits. Assuming that nutritious food is available and accessible, the household has to decide what food to purchase and how to prepare it as well as how to consume and allocate it within the household. Another aspect is the biological utilization. This relates to the ability of the human body to take food and convert it into nutrients necessary for the growth and development of the body. Beside that utilization requires a healthy physical environment and adequate sanitary facilities as well as the understanding and awareness of proper health care, food preparation, and storage processes. Stunting rate, wasting rate, prevention of diarrhoeal diseases, latrine usage, weight-for-age, goitre, anaemia and night blindness are some of the indicators at different level for this dimensions, which can be assessed by demographic and health survey, immunization chart, among others (Bajagai, 2010).

Stability

Stability describes the temporal dimension of food and nutrition security, respectively the time frame over which food and nutrition security is being considered. This dimension addresses the stability of the other three dimensions over time. Stability is given when the supply on household level remains constant during the year and in the long-term. That includes food, income and economic resources. Individuals cannot be considered food secure until they feel so and they do not feel food secure until there is stability of availability, accessibility and proper utilization condition (Bajagai, 2010).

Stability dimension of food security can be assessed by global information early warning system, anthropometric survey, or weighing chart of pregnant women against certain indicators such food price fluctuation women's BMI, pre-harvest food practice, and migration. Instability of market price of staple food and inadequate risk baring capacity of the people in the case of adverse condition such as natural disaster and unexpected weather, political instability and unemployment are the major factors affecting stability of the dimensions of food security (Bajagai, 2010).

Interventions to address this dimension are saving and loan policy, inter-household food exchange, grain bank, food storage, among others. Furthermore it is important to minimize external risks such as natural disaster and climate change, price volatility, conflicts or epidemics through activities and implementations improving the resilience of households. Such measure include insurances e.g. against drought and crop failure as well as the protection of the environment and the sustainable use of natural resources like land, soil and water. Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status (FAO, 2008b).

The element of time is concerned with having secure access to enough food at all times. The issue of time is discussed in relation to chronic and transitory food insecurity. Essentially, following the World Bank (1986), most authors distinguished between chronic and transitory food insecurity. Transitory and chronic food security or insecurity has to do with the duration (period) within which food is readily available or unavailable to the household; being it temporary or continuously.

According to Maxwell and Smith (1992), chronic food insecurity means that a household runs a continually high risk of inability to meet the food needs of household members whiles transitory food insecurity occurs when a household faces a temporary fall in the security of its entitlement and the risk of inability to meet food needs is of short duration. Transitory food insecurity, on the other hand, focuses on intra- and inter-annual variations in household food access. It has been argued that this category can be further divided into cyclical and temporary food insecurity. Temporary food insecurity occurs for a limited time because of unexpected conditions such as drought, excessive rainfall or fire outbreak. On the other hand, cyclical or seasonal food insecurity occurs when there is a regular pattern in the periodicity of inadequate access to food. This may be due to logistical difficulties or prohibitive costs in storing food or borrowing (Maxwell & Smith, 1992).

Measurement of Food Security

Measurement of food security is focused on chronic hunger and poverty. The analytical implications of the commitment to half the number of undernourished people are reflected for example in State of Food Insecurity (SOFI, 2001). However, in the official literature, hunger and undernutrition are assumed synonymous. Undernutrition is the result of undernourishment, poor absorption and/or poor biological use of nutrients consumed. Undernourishment is when food intake is continuously insufficient to meet dietary energy requirements (Kuwornu et al., 2013).

Ideally, estimates of undernutrition would be based on combined health and nutritional assessments, including anthropometry. The assessment would be for a representative cross-sectional sample population, stratified to ensure adequate representation of at-risk populations by category and region. Practically, such surveys are uncommon, especially in those countries where undernutrition is likely to be most pervasive. Consequently, measurement is typically indirect and based on food balance sheet and national income distribution and consumer expenditure data. The line of reasoning linking hunger and undernutrition with inadequate food intake allows the measurement of food insecurity in terms of the availability and apparent consumption of staple foods or energy intake (SOFI, 2001). This definition is again broadly equivalent to the earlier narrower definitions of chronic food insecurity (World Bank, 1986).

The international comparison of country estimates of chronic food insecurity therefore reflect cross-sectional patterns and trends in food production, supplemented by what is recorded about trade in basic foodstuffs (effectively cereals) as incorporated into national food balance sheets. From these comparisons broad differences in food security are apparent between the development categories of low, middle and upper income countries and also considerable variance within categories. However, the attempt to explain such differences within categories and changes over time in the incidence of undernutrition have met with limited success. State of Food Insecurity (FAO, IFAD & WFP, 2015) notes that groups of variables that reflect shocks and agricultural productivity growth are significant in explaining periodic differences in country performance but it concludes that attempts to seek one simple cause for either good or bad performance are not very useful. The power of just a few variables to explain changes in highly diverse and indeed unique national situations are limited (FAO, 2002).

Some of the factors which make this form of statistical investigation should be noted – the association of a single dependent variable to represent chronic food insecurity with proxy variables for differences amongst countries and changes in agricultural trade regime - unpromising for the study on food security. There is the unavoidable problem of unreliable data on production, and the incidence of unrecorded trade that may be most serious for many of the most food insecure countries in Sub-Saharan Africa. However, there is currently much debate about the reliability of food production data, particularly for roots and tubers in food crisis.

There is an important intra-country gap in analyses of food insecurity with national or individual focus, as reflected either in averages derived as ratios of national aggregates or a national survey estimate. That gap is most apparent for larger countries such as Brazil, India, Nigeria or Russia. There are likely to be substantial intra-country regional or zonal differences in the structure and dynamics of food security – for example as a result of more rapid agricultural development in the Punjab and Haryana States in India or temporarily because of drought in Northern Nigeria (FAO, 2002).

Food security metrics may focus on food availability, access, utilisation, the stability of food security over time, or some combination of these domains. These metrics may draw from data at national, regional, household, and/or individual levels. Such tools may vary from simple indicators for which data can be quickly collected and easily analysed to comprehensive measures that require detailed, time- and resource-intensive data collection and sophisticated analytic skills to yield results. Food security measures may rely on data from hypothesized determinants of food security or on data from purported consequences of food security (Jones et al., 2013).

The diversity of food security measurement tools currently available provides a rather vertiginous options, such that it may not always be clear how the measures differ in their conceptualizations of food security and for what purpose a given tool may best be used. The validity of a measurement tool is inseparable from the purpose for which it is intended. Identifying the intended use of a tool and understanding the underlying construct(s) it measures are critically important for determining which metric one should use. The consequences of selecting an inappropriate metric could include: 1) measuring an unintended domain or loci of food security; 2) measuring multiple domains or loci without the ability to differentiate between them; 3) collecting information that is not relevant to those for whom the data will be collected and used; 4) collecting data at an inappropriate scale; 5) collecting data that cannot be measured multiple times at the needed time intervals; or 6) selecting a tool that requires resources beyond those available for adequate data collection and analysis (Jones et al., 2013).

Jones et al. (2013) and Lawrence et al. (2016), gave a lurid review on common food security metrics and present information on what they measure, their stated purpose, the source(s) of the data used, and how these characteristics compare across metrics. These descriptions are presented according to their levels of measurement. The three main categories of levels of measurement identified as the most commonly discussed in recent food security literature by these and other authors are individual, household and cross-national levels of measuring food security. The individual level measurement mostly employs anthropometry as one of the most popular approaches to measuring food security and is thought to address the FAO's "utilisation" pillar. This broad category includes such measures as wasting, stunting, and body mass index (BMI). Anthropometry also incorporates the issue of weight that is not typically captured in household-level surveys (Segall-Corrêa, Marin-León, Pérez-Escamilla, & Melgar-Quiñonez, 2014; Lawrence, 2016). Coates (2013) and Anema et al. (2014), cited in Lawrence et al. (2016) argue that anthropometry can be problematic because it may conflate outcomes with causes, as anthropometric measures generally reflect nutritional status which is not only determined by food security status, but also by health, hygiene, and access to clean water and services. Another individual-level approach to measuring food security is through nutritional dietary surveys. However, these are complicated, expensive, and labour-intensive, so it can be challenging to get a large enough sample size to make statistically significant claims (Moltedo, Troubat, Lokshin, & Sajaia, 2014; Jones, Ngure, Pelto, & Young, 2013; Lawrence et al., 2016).

At the household levels of food security measurement the Household Consumption and Expenditure Surveys (HCEs) are used where household surveys yield information about household expenditure decisions and take the actual demographic structure of the household into account (de Haen, Klasen, & Qaim, 2011; Lawrence et al.,2016). However, HCEs do not take into account seasonal fluctuations in food availability or that food consumed outside of the home (de Haen et al., 2011). They are also costly to implement and tend to be infrequently administered (de Haen et al., 2011; Jones et al., 2013). Additionally, they usually only collect food data for a short reference period and inaccurately assume that household food consumption is the same as household food acquisition (de Haen et al., 2011, Jones et al., 2013). Other authors critical of HCE-based approaches to food security measurement note that household surveys typically do not include information on the broader structural determinants of food security like social, economic, and agricultural policies (Ghattas, 2014). Moreover, all households including low-income ones, generate some amount of food waste that is not accounted for (Moltedo et al., 2014). Jones et al. (2013) also argued that experience-based measures are also subject to response bias deriving from unique personal and cultural values, individual responses that may not reflect the opinions of the household, and recall bias of food consumption periods.

Perhaps most importantly from a measurement perspective, recent research suggests HCE results can vary significantly based on survey design, with some authors arguing HCEs should only be used with great caution until more consistent and comparable survey data collection can be completed (Carletto, Zezza, & Banarjee, 2012; de Weerdt, Beegle, Friedman, & Gibson, 2014).

Food security measures developed for use at the country level often emphasize food availability (Jones et al., 2013). The three most commonly used measures of food security under the cross-national level are Prevalence of Undernourishment (POU) developed by FAO, Global Hunger Index (GHI) developed by The International Food Policy Research Institute (IFPRI) and Global Food Security Index (GFSI) developed by Economic Intelligence Unit, which was sponsored by DuPont. National-level food security estimates may be viewed as yardsticks for cross-national comparisons and monitoring changes in macro-level trends (e.g., for monitoring progress toward achieving the Sustainable Development Goals). However, the types and sources of data used, the assumptions made when calculating food security, and the intended purpose of different measures will inform the accuracy and interpretation of results (Jones et al., 2013).

Prevalence of undernourishment

The FAO prevalence of undernourishment (POU) is one of the most common cross-national measures and it is published every three years in "The State of Food Insecurity in the World (SOFI)" to inform the global community about levels and trends of undernourishment. For many years, the POU was the main indicator used by the FAO to monitor the long-term global evolution of chronic food deprivation (FAO, 2018). This measure was also used to track progress on the first Millennium Development Goal (de Haen et al., 2011; Lawrence et al., 2016). Based on the notion of an average individual in a reference population, the POU compares usual food consumption, expressed in terms of dietary energy (kilocalories), with calorie requirement norms (Naiken, 2002).

The POU is an oft-critiqued yet still-valuable measurement because calories available per capita is comparable cross-nationally and measures are available every year because it is not measured at the individual or household level (Lawrence et al., 2016). However, as a stand-alone measure, it does not capture the complexity of all dimensions of food security (Berry, Dernini, Burlingame, Meybeck, & Conforti, 2015), though it does help evaluate food supply and shortages (Jones et al., 2013). PoU only measures the share of the population below a certain food security threshold; it cannot measure the severity of hunger for those people suffering from it. Moreover, as other similar indicators, it is based on dietary energies intake and misses the more qualitative aspects of hunger, such as nutrient deficiency that stems from a lack of diet diversity (FAO, 2018).

In addition, national-level measures do not identify equality issues at the subnational level and may not represent the food security status of minority groups, women, children or others (de Weerdt et al., 2014). Tools for measuring food availability, such as food balance sheets, have traditionally drawn from nationally aggregated data on food supply (i.e., total amount of food produced and imported) and utilisation [i.e., the quantity of food exported, fed to livestock, used for seed, processed for food and non-food uses, and lost during storage and transportation (FAO, 2001)].

Although food supply and utilisation data are useful for estimating food shortages and surpluses, developing projections of future food demand, and setting targets for agricultural production (FAO, 2001), they operate under the strong assumption that the mean of the distribution of calorie consumption in the population equals the average dietary energy supply (FAO, World Food Programme, & IFAD, 2012). But this is a problematic assumption. Even allowing for the lack of reliable information on food losses and food distribution in food balance sheet data, large disparities have been observed between the number of food-insecure households estimated by these data and estimates made by the USDA (Barrett, 2010). The USDA estimates, e.g., use projected calorie consumption estimates for different income groups based on income distribution data in addition to aggregated estimates of food supplies (Shapouri, Rosen, Meade, & Gale, 2009; Jones et al., 2013).

For this and other reasons, the FAO now publishes a set of additional food security indicators along with estimates of its “prevalence of undernourishment” measure. These metrics examine variations of the dietary energy supply and undernourishment measures (e.g., share of energy supply derived from cereals, roots, and tubers; average supply of protein of animal origin; prevalence of undernourishment considering energy needs for higher amounts of physical activity, etc.) as well as information on food prices using data on country purchasing power parities and inflation rates and food deficits (FAO, WFP, & IFAD, 2012). These additional indicators offer complementary data for interpreting undernourishment estimates and begin to assess food security components beyond just food availability.

The global hunger index

The Global Hunger Index (GHI) was developed by IFPRI. The main focus of the GHI is to measure hunger using 3 equally weighted indicators: 1) undernourishment (i.e., the proportion of undernourished people as a percentage of the population); 2) child underweight (i.e., the proportion of children younger than 5 years who have a low weight for their age); and 3) child mortality (i.e., the mortality rate for children younger than age 5 years) (IFPRI, 2012). Countries are ranked on a 100-point scale and categorized as having "low" to "extremely alarming" hunger (Jones et al., 2013). Data for the child mortality and undernourishment components of the index are derived from UNICEF and the FAO, respectively. The child underweight component of the index comes from the WHO Global Database on Child Growth and Malnutrition, Demographic and Health Survey data, and UNICEF's Multiple Indicator Cluster Survey reports (Jones et al., 2013).

The stated purpose of the index is to underscore successes and failures in hunger reduction and raise awareness and understanding of regional and country differences in hunger (IFPRI, 2012). The term "hunger" as used here ostensibly represents a manifestation of severe food insecurity. However, the component measurements of the

GHI also reflect child health and undernutrition, the determinants of which are not necessarily associated with food insecurity. Interpretation of the GHI as a measure of food security or hunger, then, becomes complicated by this additional information captured by the index.

The global food security index

The Global Food Security Index (GFSI) is another multi-dimensional tool for assessing country-level trends in food security. It was designed by the Economist Intelligence Unit and sponsored by DuPont (Jones et al., 2013). The index uses a total of 30 indicators within 3 domains of food security; affordability (6 indicators), availability (10), and quality and safety (14) to provide a standard against which country-level food security can be measured (Economist Intelligence Unit, 2012). Similar to other national-level metrics, the GFSI ranks the performance of countries in achieving food security, but it does so using quantitative and qualitative indicators that reflect not only food availability, but food access (e.g., food consumption as a proportion of total household expenditure, proportion of population living under or close to the global poverty line, food prices) and diet quality (e.g., dietary availability of micronutrients). The GFSI is recalculated quarterly based on shifts in food price data (Jones et al., 2013).

In addition to relying on data from the Economist Intelligence Unit, World Bank, FAO, WFP, and the World Trade Organization, the GFSI relies on expert panels and analysts from the academic, non-profit, and public sectors. These experts provide subjective scoring to create many of the qualitative indicators that inform the index, assign weights to the indicators, and, in fact, select the indicators that are included in the index. This reliance on expert opinion and consensus departs from the FAO and IFPRI approaches discussed above. However, subjective interpretation of data is, in fact commonly used for developing food security metrics. Indeed, the complexity of factors contributing to food security and the importance of context in interpreting these factors have led to some institutions prioritizing consultative methods for developing food security measurement tools (Jones et al., 2013).

Famine early warning systems network

The Famine Early Warning Systems Network (FEWS NET) is a network of international and regional partners funded by USAID. It produces monthly food security updates for 25 countries. The intent is to provide evidence-based analysis to support decision makers in mitigating food insecurity (Funk & Verdin, 2010). Regional teams monitor and analyse a potpourri of information that could include data on long-term and real-time satellite rainfall records, the Normalized Difference Vegetation Index, temperature, agricultural production, prices, trade, economic shocks, political instability, and local livelihoods (Funk & Verdin, 2010, cited in Jones et al., 2013). FEWS NET was initially created to help avert emergency famine situations such as those that occurred in Sudan and Ethiopia in the mid-1980s. However, the network has since evolved to monitor not only droughts and crop failures that cause acute food insecurity but also the underlying causes of chronic food insecurity, such as persistent poverty and livelihood vulnerability. In an attempt to align with a global standard for food security classification, FEWS NET transitioned its classification system to the Integrated Food Security Phase Classification (IPC) system in April 2011 (IPC, 2012; cited in Jones et al., 2013).

The integrated food security phase classification

The Integrated Food Security Phase Classification is a set of protocols for broadly evaluating the food security condition within a given region (Global Partners IPC, 2012). It draws data from a wide range of sources to establish common classifications for the severity and magnitude of food insecurity in specific circumstances. The main intention of the IPC is to identify the severity and magnitude of food insecurity in a given region, compare food security outcomes, and identify strategic action objectives across contexts based on the classifications (Haan, 2012; cited in Jones et al., 2013).

The IPC depends on data from Demographic and Health Survey and Multiple Indicator Cluster Survey, household budget surveys, and consultations with government and nongovernmental organization authorities. Another key input into the IPC classification approach is the WFP's Comprehensive Food Security and Vulnerability Analyses (CFSVAs). Similar to the GFSI, the IPC approach relies on building consensus among a team of multi-sectoral experts who are brought together to evaluate and debate evidence with key stakeholders (Global Partners IPC, 2012). Food insecurity phases are assigned by these experts ranging from "minimal" to "stressed," "crisis," "emergency," or "famine." These classifications can be applied to geographic scales ranging from villages to provinces. The analysts also assign heuristic reliability scores to each data source that contributes to the classifications and assign a confidence level to the final phase classification (Haan, 2012). Thus, the IPC approach is not a model-based approach but rather a consultative one that relies on the subjective interpretation by experts of accumulated evidence from multiple domains, including food consumption, livelihood change, nutrition and health, and hazards and vulnerability (Global Partners IPC, 2012; Jones et al., 2013).

Consolidated Approach for Reporting Indicators of Food Security

The United Nations World Food Programme has developed a standardised approach for assessing and reporting household food security called the consolidated approach for reporting indicators of food security (CARI) (WFP, 2015). This approach culminates a food security console, which supports reporting and combining food security indicators in a systematic and transparent way, using information collected in a survey. Central to the approach is an explicit classification of households into four descriptive groups: food secure, marginally food secure, moderately food insecure, and severely food insecure. The classification provides a representative estimate of food insecurity within the target population whether it is calculated at the national, district, region or livelihood level.

The console's domains represent two key dimensions of food insecurity. The first domain measures current food security status by employing food security indicators that measure the adequacy of households' current food consumption. This domain is based on the food consumption score and/or food energy shortfall indicators. The second domain, which is referred to as the coping capacity domain, employs indicators which measure households' economic vulnerability and/or asset depletion. Specifically, this domain is based upon a combination of the livelihood coping strategy indicator and either the food expenditure share indicator or the poverty status indicator.

When the data are available, the CARI console uses food consumption group data (based on the food consumption score or FCS) as a descriptor of a household's current status of food consumption. The FCS is a proxy of households' food access and a core indicator used to classify households into different groups based on the adequacy of the foods consumed in the week prior to being surveyed. It represents households' dietary diversity and nutrient intake. The FCS is calculated by inspecting how often households consume food items from the different food groups during a 7 day reference period. The FCS was first created in Southern Africa in 1996, and has been in use there as part of the Community Household Surveillance (CHS). Extensive testing and application of the FCS has validated its use in this region and context. Additionally, the FCS is now being tested and applied in other countries and regions (WFP, 2008). The FCS is the core indicator of consumption recommended by Vulnerability Analysis and Mapping (VAM).

The console's Coping Capacity domain aims to measure households' resilience to potential shocks. The CARI console considers two dimensions of household coping capacity: economic vulnerability and asset depletion. In the CARI console, a household's economic vulnerability is determined using either the poverty status (based on the national poverty line), or the share of household expenditures spent on food. While the former indicator provides a stronger estimate of household vulnerability, it is unlikely to be available for most food security assessments. It is important to note that only one of the two 'economic vulnerability' indicators should be used (i.e. either poverty status or food expenditure share, but not both) (WFP, 2015). When the survey cannot generate poverty line data, economic vulnerability is measured using the 'food expenditure share' indicator. This indicator is based on the premise that the greater the importance of food within a household's overall budget (relative to other consumed items/services) the more economically vulnerable the household (WFP, 2015).

The food expenditure share indicator is essentially constructed by dividing the total food expenditures by the total household expenditures. However, an important caveat is that both the denominator and numerator should include the value of non-purchased foods consumed. By including both non-purchased foods and purchased foods within the overall food expenditure share estimate, the indicator considers households with different food access situations similarly. However, the measure of economic vulnerability is concerned chiefly with how much (proportionately) of the household's total expenditures, is directed to non-food items. In other words, how bigger role does food play with respect to the consumption of other non-food items (WFP, 2015).

The CARI uses the Livelihood Coping Strategies indicator as a descriptor of a household's coping capacity. The Livelihood Coping Strategies indicator is derived from a series of questions regarding the household's experience with livelihood stress and asset depletion during 30 days prior to the survey. Responses are used to understand the stress and insecurity faced by households and describe their capacity regarding future productivity. All strategies are classified into three broad groups, including stress, crisis and emergency strategies.

- Stress strategies, such as borrowing money or spending savings, are those which indicate a reduced ability to deal with future shocks due to a current reduction in resources or increase in debts.
- Crisis strategies, such as selling productive assets, directly reduce future productivity, including human capital formation.
- Emergency strategies, such as selling one's land, affect future productivity, but are more difficult to reverse or more dramatic in nature.

Households engaging in routine economic activities that did not involve any of these strategies would be considered equivalent to food secure on this indicator.

The CARI methodology is designed to be used for food security assessments that aim at estimating the actual number of food insecure households in a target population. The method is suitable for national and regional assessments, as well as more specific locations. It requires data sourced entirely from a single household-level survey. The food security console can be prepared for all geographic levels (i.e. national; urban/rural; district; livelihoods; etc) and other strata (e.g. livelihood activities, sex of household head) (WFP, 2015).

Limitations of the CARI approach

There are a number of limitations to the CARI. First, as it usually happens, whenever multiple data from different dimensions are summarized into one summary indicator, there is a loss of information. That certainly is the case here, where averaging together of current food consumption with coping capacity gives one an indicator that cannot distinguish, for example, between a household with poor consumption today, but adequate coping capacity and a household in the opposite situation. A second concern has to do with the very idea of a global indicator. While standardized indicators are helpful for agencies or donors that work globally across a number of countries or regions, taking action on the ground often requires more specialized information, developed to capture local nuances. The intention of this approach, however, is to make available a suite of indicators, so that information on a number of dimensions of the problem is provided, in addition to the summary indicator (i.e. the food security index).

Thirdly, the combinations of indicators used within the CARI are likely to change. Since different countries, regions and localities have different food security situations, there is the need to understand how sensitive the CARI is to specific conditions of different countries or localities, and this may result in the introduction of new indicators which are designed to measure food security. Eventually, some minor adjustments and inclusions may take place (WFP, 2015). The integrated food security phase classification (IPC) is an important approach for combining food security indicators in a way that is standardized and useful as a first step in making programming and policy decisions. Essentially, each IPC takes the form of a national forum that conducts a joint food security analysis using secondary data to reach technical consensus on the nature and severity of that country's food insecurity. Following the forum, the IPC results are consolidated into a report containing the key findings of the analysis and the 'IPC severity phases' map. The IPC is endorsed by a number of international organizations. The IPC approach combines conceptual frameworks on risk and vulnerability, sustainable livelihoods, and the causal framework on nutrition with the four basic dimensions (availability, access, utilisation, and stability) of food security analysis (WFP, 2015).

Household-Level Food Security Measurement

Although some of the food security measurement tools described so far assess more than just available national food supplies, they also do not emphasize household-level behaviours and determinants of food access because of their focus on national- or regional-level estimates and trends. Household-level measures of food security are concerned with food security dynamics between and within households. Because these measures rely on data from household surveys, they are able to more accurately capture the "access" component of food security than measures that rely on nationally pooled data (Jones et al., 2013). Food access refers to physical and economic access to food;

however, many of the tools used to measure food access actually measure food acquisition or food consumption. These concepts are commonly used interchangeably to refer to food access, yet they are important to distinguish for measurement purposes.

Household consumption and expenditure surveys

Data on household food consumption and expenditures from household-level surveys are becoming more imperative for assessing household food acquisition. The FAO has resolved to make broader use of increasingly available data sets based on household consumption and expenditure surveys (HCESs) and living standard measurement surveys (Committee on World Food Security, 2011). HCESs measure poverty (i.e., monetary expenditures as a proxy for income), assess consumer price indices and household socioeconomic status (e.g., education, housing type/quality, assets, health-seeking behaviour, income), and examine patterns of food and nonfood consumption among households (Fiedler, Carletto, & Dupriez, 2012). Data on food expenditures usually reflect only the monetary value of foods. Yet more accurate measurement of household food acquisition requires estimation of the quantities of foods acquired (to be able to estimate, e.g., the quantity of foods consumed per capita, diet diversity, or dietary energy availability per capita) (Smith & Subandoro, 2007). HCESs often operate under the assumption that household food acquisition equals household food consumption. This assumption of acquisition-consumption equality may hold only for population-level estimates of food consumption (i.e., some randomly selected survey households are drawing down food stocks acquired before the survey reference period and others are purchasing new foods so that household-level differences become random error) (Smith & Subandoro, 2007). However, for household-level estimates of food security, these data may provide widely varying estimates of household food consumption that will not provide sufficiently accurate estimates for some purposes like monitoring the food security status of the same households over time. Food acquired may also be wasted, lost, fed to animals, or gifted. Thus, over- or underestimations of food intakes may result if relying solely on food expenditures data (Bouis , 1994). HCESs offer a less costly and time-consuming alternative to detailed dietary intake assessments or observed-weighed food records for assessing food consumption. Given this fact, and the expanding use and accuracy of HCESs as food security-monitoring tools in many countries, these data will likely make increasing contributions to estimates of food acquisition worldwide (Jones et al., 2013). Similarly, the fact that HCES data do not account for individual consumption, especially among vulnerable groups such as infants, young children, and pregnant and lactating women, and do not capture data on food wasted or consumed away from the household, means that other methods will continue to be needed for accurate dietary intake assessment.

The dietary diversity proxy

Dietary food group diversity is a commonly used measurement in part, because food group consumption data are easy to collect and dietary diversity consistently demonstrates positive associations with the nutrient quality of diets (Rose, Meershoek, Ismael, & McEwan, 2002; Kant, 2004; Steyn, Nel, Nantel, Kennedy, & Labadarios, 2006). Dietary diversity, however, has also gained considerable traction as an indicator of food security (Ruel, 2002). It has been shown to be associated with various measures of household socioeconomic status that are commonly considered proxy indicators of household food security, including food and non-food expenditures (Rah, et al., 2010; Thorne-Lyman, et al., 2010), per capita daily caloric availability (Hoddinott & Yohannes, 2002), household assets and education (Hatløy, Hallund, Diarra, & Oshaug, 2000; Anzid, et al., 2009), and household income (Rashid, Smith, & Rahman , 2006). The diversity of household diets may be linked to these measures in part, because poor households will frequently use additional income to purchase non-staple foods, thereby increasing household dietary diversity (Thorne-Lyman, et al., 2010). Because the kinds of foods available to households vary widely across cultural contexts, there is no unique definition of dietary diversity for all settings. This presents a challenge to measuring dietary diversity across settings and using indicators of dietary diversity to represent the same underlying phenomenon (Jones et al., 2013).

Food consumption score

The WFP's flagship indicator for establishing the prevalence of food insecurity in a country or region is the Food Consumption Score (FCS). It is heavily informed by the linkage between dietary diversity and household food access. The FCS combines data on dietary diversity and food frequency using 7-day recall data from CFSVAs and emergency food security assessments (WFP, 2007). The respondent reports on the frequency of household consumption of 8 food groups (i.e., "staples," which include foods as diverse as maize, rice, sorghum, cassava, potatoes, millets, etc., pulses, vegetables, fruit, meat and fish, dairy products, sugar, and oil). The frequency of consumption of each food group is then multiplied by an assigned weight for each group and the resulting values are summed to obtain the FCS. This score is then recoded to a categorical variable using standard cutoff values. The assigned weights for each food group (i.e., meat, milk, and fish = 4, pulses = 3, staples = 2, vegetables and fruits = 1, sugar and oil = 0.5) were determined by a team of analysts based on the energy, protein, and micronutrient densities of each food group. "Poor" food security scores reflect the fact that households may be falling short of consuming at least one staple food and one vegetable each day of the week and “acceptable” scores are based on an expected daily household consumption of oil and pulses in addition to staples and vegetables (WFP, 2007). The FCS is intended to monitor changes in food security in countries, to identify food-insecure regions within and across countries.

Household dietary diversity score

The Household Dietary Diversity Score (HDDS) was developed by the Food and Nutrition Technical Assistance Project (Swindale & Bilinsky, 2006). The score is calculated by summing equally weighted response data on the consumption of 12 food groups (i.e., cereal grain staples, roots and tubers, vegetables, fruits, meat, eggs, fish, pulses and nuts, dairy products, oils and fats, sugar, and condiments). The individual responsible for food preparation in the household is asked if anyone in the household consumed any item from the food group in the previous 24 hours. These responses are summed to obtain a score from 0 to 12. The HDDS has no standard cut-offs for defining food insecurity though (Swindale & Bilinsky, 2006, as cited in Jones et al., 2013). Similar diet diversity scores (DDSs) have been developed to assess the nutritional quality of individual diets (Kennedy, Ballard, & Dop, 2011).

Participatory Adaptation-Based Measures of Food Security

Although the metrics of household food access examined thus far are intended for use across contexts without adaptation, measures based on participatory adaptation are informed by context specific information collected from groups of stakeholders in the communities and districts where food security will be measured.

Coping strategies index

The Coping Strategies Index (CSI), developed by the humanitarian organization CARE and the WFP, is one such example of a participatory approach to assessing food security. It employs a series of questions regarding how households cope with food shortfalls to construct a numeric score that can be used for targeting food aid, monitoring the impact of food aid, and estimating long-term changes in food security (Maxwell, Watkins, Wheeler, & Collins, 2003; Jones et al., 2013).

The CSI is constructed from a list of coping strategies that households rely on in times of food deprivation or that they may use to manage problems of food access that they think would arise in the future. Though a list of generic coping strategies is suggested along with common coping domains, a locally adapted list is generated through focus group discussions with stakeholders who represent the population of interest. Information on the relative frequency of use of the strategies over the previous month must also be collected during these interviews and combined with the information on the strategies themselves. Given that the same perceptions and behaviours do not always indicate the same severity of food insecurity across contexts (Coates, Wilde, Webb, Rogers, & Houser, 2006), a second round of focus group interviews is then suggested to assign severity weightings to the established list of coping strategies. These weightings are then grouped and scores are assigned to each group. Frequency categories are also assigned scores and all of the information is combined to yield a final index score from household survey data that incorporate questions on the identified coping strategies (Jones et al., 2013).

The final CSI score for any given household is not very meaningful by itself. However, when compared with CSI scores calculated for other households in the same community or region using the same adapted index or when comparing scores on the same households over time, the CSI serves as a comparative indicator of household food security (Maxwell, Watkins, Wheeler, & Collins, 2003; Jones et al., 2013).

A reduced version of the CSI has been developed that uses only the 5 most common coping strategies employed in response to food shortages as reported from a selection of survey data that incorporate the CSI (Maxwell, Caldwell, & Langworthy, 2008; Jones et al., 2013). This reduced version of the index does not provide comprehensive information on the range of food-insecure households in a region and therefore may not be as useful for identifying vulnerable households as compared with the original CSI (Jones et al., 2013). However, measurement of the same sets of behaviours and use of standardized severity weightings allows the reduced index to more easily compare the food security status of households across contexts (Maxwell & Caldwell, 2008).

Household economy approach

The Household Economy Approach (HEA), developed in the early 1990s by the humanitarian organization Save the Children Fund in collaboration with the FAO, is another participatory approach to understanding household food security. The HEA differs from all metrics described until now in that it is an analytical framework, not a measure of food security in and of itself (FEG Consulting and Save the Children, 2008, cited in Jones et al., 2013). Yet, although the HEA is not a standard data collection tool, it prescribes a set of procedures for assessing livelihood vulnerabilities that produces information that can be used in much the same way as data generated using other food security measures. Similar to the CSI, the HEA draws largely from rapid rural appraisal techniques (e.g., semi-structured interviewing of focus groups) rather than household survey data (Jones et al., 2013).

The analysis motivated by the framework centres on a broad assessment of livelihoods, including: 1) delineating geographic patterns of shared livelihoods; 2) grouping households based on wealth and assets; and 3) categorizing household livelihood strategies (FEG Consulting and Save the Children, 2008). The analysis may be advanced further, however, to predict the effect of potential hazards on the livelihoods and food security of households through an "outcome analysis" that entails analysing potential hazards and assessing the coping capacity of households to deal with different shocks (FEG Consulting and Save the Children, 2008). The HEA has been used extensively in poverty and vulnerability assessments, especially in sub-Saharan Africa, to assess the ability of households to access food and income as well as to identify appropriate interventions to improve access in the face of specific shocks (Sawdon, 2002).

The multi-tiered approach of the HEA and its reliance on consultative, and qualitative information allow for a contextual understanding of household livelihood vulnerability in specific settings. Such information can be valuable both in emergency situations for identifying food needs as well as for longer term development efforts that require identifying poverty reduction strategies. The HEA though, unlike the CSI, is not designed to produce a quantifiable output that may be used on a larger scale in quantitative household surveys. It trades the benefits of a standard food security measure that allows for comparisons across settings for access to context-specific information on numerous domains of food security in a given region (Jones et al., 2013). This comprehensive approach may allow for more in-depth insights into the nature of food security and its determinants that simpler indicators might not detect; e.g., uncovering the importance not only of poverty and environmental stressors, but also declining social capital as drivers of food insecurity.

Direct experience-based measures

The experience-based approaches to measuring household food access attempt to directly measure families' behaviours and lived experiences of household food security using questionnaires (Barrett, 2002; Jones et al., 2013). Some of these approaches may also utilize participatory adaptation techniques; however, they differ from other approaches in that they attempt to directly measure food security (Akaba, 2008; Jones et al., 2013; Manu et al., 2013).

The use of household food security survey module

The empirically rooted, qualitative measures of food security and hunger that emerged from these ground-breaking studies informed the development of what is now known as the Household Food Security Survey Module (HFSSM), an 18-question survey module that asks families to report their subjective experiences of four (4) domains of food insecurity: 1) anxiety about household food supplies; 2) perceptions that the quality or quantity of accessible food is not adequate; 3) reduced adult food intake; and 4) reduced food intake by children (Kennedy, 2002). Households are classified as either food secure, having low food security, or very low food security depending on the number of food-insecure conditions (Coleman-Jensen, Nord, Andrews, & Carlson, 2012; Jones, Ngure, Pelto, & Young, 2013)

The HFSSM has been shown to be a valid measure of food security and hunger for populations and individuals (Frongillo, 1999). Given its strong performance measuring food security across a number of subgroups, the direct questionnaire-based measurement approach of the HFSSM was thought to have the potential to serve as a common means of measuring food security in low-income countries (Frongillo, 1999). Several studies using adapted versions of the HFSSM in sub-Saharan Africa, Latin America, and South Asia soon emerged that found the direct, questionnaire-based measure of household food security was associated with total expenditure per capita (Coates, Webb, & Houser, 2003), total daily per capita food expenditures (Coates, Webb, & Houser, 2003; Melgar-Quinonez, et al., 2006), net income per adult, total assets, and adult energy intake (Frongillo & Nanama, 2006) as well as income strata and dietary diversity (Pérez-Escamilla, et al., 2004; Jones, Ngure, Pelto, & Young, 2013).

Current Situation of Global Food Security

After a prolonged decline, world hunger appears to be on the rise again. The estimated number of undernourished people increased to 815 million in 2016, up from 777 million in 2015 (FAO, IFAD, UNICEF, WFP & WHO, 2017). This sends a clear warning signal that the ambition of a world without hunger and malnutrition by 2030 will be challenging. Thus, achieving it will require renewed efforts through effective and efficient strategies based on empirical and informed decisions.

Current global prevalence of undernourishment (PoU) estimates show that, despite significant population growth, the share of undernourished people in the world decreased from 14.7 percent in 2000 to 10.8 percent in 2013. However, this rate of reduction has slowed significantly recently, coming to a virtual halt between 2013 and 2015. Most worryingly, FAO estimates for 2016 indicate that the global prevalence of undernourishment in 2016 may have actually risen to 11 percent, implying a return to the level reached in 2012 and suggesting a possible reversal of the downward trend sustained over recent decades. The worsening was most severe in sub-Saharan Africa and South-Eastern Asia (FAO, 2017; FAO, IFAD, UNICEF, WFP & WHO, 2017). Sub-Saharan Africa also remains the region with the highest PoU, affecting an alarming 22.7 percent of the population in 2016.

Determinants of Food Security

The determinants of food security differ at different levels, that is from global to regional and national to household and individual levels. This is because food security is deemed to be a multidimensional phenomenon encompassing climate change, civil conflicts, natural disasters, and social norms (Abdullah, et al., 2017).

As reported by Abdullah, et al. (2017), a number of factors influence household food security including household assets (Guo, 2011); homeownership (Rose et al., 1998); financial constraints (Chang et al., 2014); access to credit (Gundersen & Gruber, 2001; Ribar & Hamrick, 2003); education (Kidane et al., 2005); levels of income (Loopstra & Tarasuk, 2013); knowledge of the household about food storage, processing, nutrition and management of illness (Riely et al., 1999); corruption, fiscal imprudence, huge debts and policy inconsistency (Akpan, 2009); non-farm work (Owusu et al., 2011); gender of the household head (Kassie et al., 2014); size of the family, cultivated land size, fertility of soil, irrigation access, number of extension visits, fertilizer use and improved seed (Bogale, 2012); remittances and access to market information, and age of the household head (Mango et al., 2014); dependency ratio, irrigation availability (Asghar & Muhammad, 2013); monthly income, structure of the family (Bashir et al., 2013); and infrastructural availability (Gill & Khan, 2010)

Abdullah, et al. (2017) again argued that though about 90 percent of the rural population in Sub-Saharan Africa depends on agriculture for their livelihoods, they still suffer from food insecurity challenges, and this is mainly due to low productivity and belligerent agro-ecological factors. De Cock, et al. (2013) also posited that human capital (education), household size, dependency ratio, household income and geographical location of respondents are important determinants of food security levels.

The external environment in which people live determines household food security. Within the external environment, critical trends (e.g. population growth, national and international economic trends, governance and technological changes), seasonal cycles (of prices, production, livelihood strategies), and shocks (natural and man-made) frame the vulnerability context. Within that vulnerability context, the risk to food insecurity is defined as the interaction between the probability of a given hazard of certain intensity, the vulnerability of the population to the hazard and the size of the population (WFP, 2001). However, Kuwornu et al. (2013) explained that food access is determined by physical and financial resources, as well as by social and political factors.

Lack of education is closely associated with food insecurity. Half of the food insecure households were headed by individuals who had never received any schooling in their life. Similarly, their own children were found to be less likely to attend school, spinning the intergenerational cycle into motion. Lack of education will hamper their children's' potential to escape from the food insecurity-poverty trap in the future (WFP, 2001).

High dependency on agricultural livelihood activities as primary income source has been found to increase vulnerability to food insecurity. The large majority of small holder farmers and agro-pastoralists apply traditional, often inefficient agricultural practices and are entirely dependent on rain for cultivation. The average productivity of maize cultivated without improved inputs, irrigation and extension support - which is the norm - is four times below its potential (WFP, 2001).

Extension services that provide agricultural support and advice to remote farming households are greatly limited. This general lack of incentives drives young people out of the rural areas, leaving the farming population with limited labour further increasing their vulnerability. Lack of access to output markets are well-known barriers to farming households that discourage them to produce beyond their subsistence needs and build on their potential (WFP, 2001).

Empirical Review of Food Security

In the African contexts, the FCS has been shown to be positively associated with kilocalories consumed per capita per day, asset indices, and total monthly household expenditures (WFP, 2007) and in a validation study using data from Burundi, Haiti, and Sri Lanka, the score demonstrated positive associations with calorie consumption per capita (Wiesmann, Bassett, Benson, & Hoddinott, 2009). This same validation study also found, however, that the cut-offs for determining levels of food insecurity severely underestimated food insecurity as measured by calorie consumption per capita and that the weightings of food groups did not improve associations with energy intake (Wiesmann, Bassett, Benson, & Hoddinott, 2009). The cut-offs for the FCS may also need to be adjusted upwards in situations where nearly all households consume sugar and oil regularly, effectively establishing a minimum FCS of 7 for all households (WFP, 2007). The standardization of cut-offs and weightings for the FCS allows for greater comparability of the score across contexts. However, these weightings may obscure important national or regional differences. For example, in regions where fruits and vegetables are not easily accessible to some families consuming these food groups may be an indication of food security, yet the weighting of fruits and vegetables in the FCS calculation (i.e., lower than staple foods) may hide this important dynamic. In addition, the positive associations observed between the FCS and household calorie consumption do not necessarily equate to positive associations with nutrient intakes (Jones et al., 2013).

The HDDS and slight variations of it have been shown to be positively associated with household food security as measured by a weighted sum of coping strategies, a lower odds of having inadequate calorie availability at the household level (Hillbruner & Egan, 2008), and employment and income (Tawodzera , 2011; Jones et al., 2013).

The CSI, both in its original and reduced forms, has been shown to be positively correlated with household assets, total expenditure per capita, and percentage of expenditures on food in several sub-Saharan African countries (Maxwell & Caldwell, 2008, Jones et al., 2013).

A meta-analysis of 49 case studies that used the HEA to assess household vulnerability to food insecurity in southern Africa revealed poverty, environmental stressors, and conflict to be the direct causes of inadequate food access in the region (Misselhorn, 2005). Use of the HEA also identified deteriorating social capital (e.g., loss of social connectedness, reciprocity, trust relations, and social networks, and the disintegration of family units) as a fundamental driver of increasing vulnerability in the region (Misselhorn, 2005).

De Cock et al. (2013) examined the food security situation in Limpopo Province of South Africa using mixed method and found that majority of the rural households (53.0%) were food insecure.

Concepts of Production Sustainability

The understanding and definition of sustainable agriculture differs among different countries, sometimes even between regions. At present there is no stable definition of sustainable agriculture which would include the list of well- defined criteria. Often sustainable agriculture is more of a philosophy than a farming practice and a life style. Its definition is therefore needed, and it should include comparable standards as well as understanding and implementation of farming practices which can highly contribute to overall sustainable development of an area and on the global level (Erker, et al., 2013). Sustainable agricultural production is a system of agriculture in which food and fibre is produced using agricultural technologies and methods to conserve natural resources while ensuring a social, economic, and ecological continuity or improvements sustainable agricultural production was also defined by the American Society of Agronomy, as agriculture that over the long term enhances environmental quality and the resource base on which agriculture depends, provides the basic food and fibre needs, is economically viable, enhances the quality of life for farmers and society as a whole (Muma, 2006).

Sustainability in agriculture is a complex concept which has evolved since the early 1980s in response to an array of ecological and equity problems posed by the adoption of modern industrial agriculture (Amekawa, 2010). Some argue that the concept of sustainability is a "social construct". To some extent, what is defined as sustainable could vary based on the perspectives of the analysts (David, 1989; Webster, 1999). From the inception, the concept has been inseparably tied to the critique of conventional agricultural paradigm. Broadly, the critique focuses on equity and environmental dimensions. The most commonly cited critique with regard to the equity dimension is the fact that the adopted technologies are not scale neutral but favors resource rich farmers at the expense of poor farmers who could be displaced without adequate safety nets (Altieri, 2000; Amekawa, 2010).

Another critique is related to the labour saving innovations. An increased intensification of capital through the introduction of high-input agricultural technology (such as heavy machinery, irrigation, high-yielding varieties, and agrochemicals) liberates affluent farmers from a hired labour force while forcing the displaced landless cohorts into urban slums and shanty towns (Tadaro, 1996, cited in Amekawa, 2010). In addition, sustainable agriculture supporters are critical of the conventional agricultural extension strategies. The adopted 'transfer-of-technology' model, which promotes a top-down transmission of agricultural knowledge from extension officers to farmers, bolsters conventional agriculture by converting component research into easily transmittable production recommendations (Chambers, 1989), while bypassing small-scale farmers' own needs and insights and ignoring holistic ecological approaches (Amekawa, 2010).

Further, sustainability proponents call against indiscriminate use and ineffective regulation of pesticides, particularly in developing countries where many pesticides banned in industrialized countries are still being used. Poor farmers and farm workers are the most affected victims of pesticide intoxication due to their low educational backgrounds and the lack of protection measures (Murray 1994; Wright 2005; Amekawa, 2010). On the ecological dimension, the concept of sustainable agriculture reflects a critical view of monoculture, because intensive monocropping in pursuit of economies of scale is prone to a significant biodiversity loss. It is also susceptible to several unintended ecological outcomes like pest outbreaks that arise from reduced environmental opportunities for natural enemies and transformation of pest genetics to resist frequently used pesticides. Crop failures due to such ecological chaos may lead to a severe economic loss and serious debt problems for less affluent farmers (Murray 1994; Wright 2005; Amekawa, 2010).

Moreover, the concept highlights the ecological unsustainability that a heavy application of Green Revolution technologies may bring on. The use of synthetic pesticides and fertilizers, improved seeds generated through plant breeding and genetic engineering, and associated irrigation systems may result in high costs and environmental externalities, such as soil erosion, salinization, chemical pollution, and loss of native crop genetic diversity and reduction in overall biodiversity (Altieri & Nicholls, 2005; Amekawa, 2010).

Sustainable agriculture therefore encompasses a range of agricultural systems such as: organic farming, ecological farming, indigenous technical knowledge, biodiversity, regenerative farming, and integrated pest management among others (Conway, 1997). A range of meanings of sustainable agriculture is therefore expected to occur according to the goal, location, means and time scale that fits the needs of individual regarding sustainable agriculture. Production sustainability involves a way of trying to address the technical and socio-economic problems in agricultural systems both from a technical and normative way. Sustainable agriculture is therefore both a philosophy and a system of agricultural practices (Macrae, 1993 cited in Muma, 2006).

Theoretical discussions are attending the challenges of disciplinary and methodological heterogeneity. The quest to define sustainability through biophysical assessment has brought distributional issues to the fore, initiating preliminary interaction with the social sciences and humanities (Hezri, 2005; Miller, 2005). Another important theoretical output is the availability of various methodologies in aggregating raw and incongruent sustainability variables through indices development. The existing indicator systems in the realm of policy are becoming instrumental in mainstreaming sustainable development as a policy goal. Following persistent applications across time at various levels of government, the PSR model has aggregate an enormous amount of data previously inaccessible, a prelude for the much needed long-term trend monitoring that is important for governments to prioritize actions. The growing global interest in ecological monitoring not only contributes in improving information accessibility, but in generating more data for environmental policymaking (Hezri & Dovers, 2006 cited in Hayati et al., 2006).

Sustainable Intensification

The desire for agriculture to produce more food without environmental harm, or even contributing to natural and social capital improvement, has been reflected in calls for a wide range of different types of more sustainable agricultural production practices (Pretty & Bharucha, 2014). As proposed by Pretty (2008), Royal Society (2009) and Pretty & Bharucha (2014), sustainable production systems should exhibit a number of key features at the production end of food systems. These features should be characterised by the following:

1. Utilization of crop varieties and livestock breeds with high productivity with regards to use of inputs;
2. avoidance of unnecessary use of external inputs;
3. harnessing agro-ecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism;
4. minimizing the use of technologies or practices that have adverse impacts on the environment and human health;

5. making productive use of human capital in the form of knowledge and capacity to adapt and innovate and of social capital to resolve common landscape-scale or system-wide problems (such as water, pest or soil management); and
6. minimising the impacts of system management on externalities such as GHG emissions, clean water, carbon sequestration, biodiversity, and dispersal of pests, pathogens and weeds.

Sustainable agricultural production systems capitalize on the synergies and efficiencies that arise from complex ecosystems, social and economic forces (NRC, 2010). These systems are diverse, synergistic and tailored to their particular social and ecological contexts. There are many pathways towards agricultural sustainability, and no single configuration of technologies, inputs and ecological management is more likely to be widely applicable than another. Agricultural sustainability implies the need to fit these factors to the specific circumstances of different agricultural systems (Horlings & Marsden, 2011; Pretty & Bharucha, 2014).

Sustainable production systems often involve complex diversity of plant species and associated management techniques, which require certain levels of competencies by farmers. To increase production efficiently and sustainably, farmers need to understand under what conditions production resources such as seeds, fertilizers and pesticides can either complement or contradict biological processes and ecosystem services that inherently support agriculture (Settle & Hama Garba, 2011; Royal Society, 2009; Pretty & Bharucha, 2014).

Conventional thinking about agricultural sustainability has often assumed that it implies a net reduction in input use, thus making such systems essentially extensive (requiring more land to produce the same amount of food). Organic systems often accept lower yields per area of land in order to reduce input use and increase the positive impact on natural capital. However, such organic systems may still be efficient if management, knowledge and information are substituted for purchased external inputs. Recent evidence shows that successful agricultural sustainability initiatives and projects arise from shifts in the factors of agricultural production (e.g. from use of fertilizers to nitrogen-fixing legumes; from pesticides to emphasis on natural enemies; from ploughing to zero-tillage). A better concept is one that centres on intensification of resources, making better use of existing resources (e.g. land, water and biodiversity) and technologies (Royal Society, 2009; NRC, 2010; FAO, 2011; Tilman, Balzer, Hill, & Befort, 2011; Pretty & Bharucha, 2014).

Determination of Production Sustainability

Many systems of sustainability indicators have been developed in recent years, including agricultural indicators. International organizations and agricultural national institutions around the world have proposed and developed a number of agriculture sustainability indicators, in order to evaluate a particular aspect of sustainability, especially at the national and farm level (Erker et al., 2013).

Considerable efforts have been made to identify appropriate indicators for agricultural sustainability. In the realm of practice, the most influential model of environmental reporting is the causality chain of Pressure-State-Response (PSR). Although its conceptual development can be traced back to the 1950s, the PSR model was pioneered by the Organisation for Economic Cooperation and Development (OECD) (OECD, 1991). The PSR model and variants have been extensively used to organise a menu of indicators. Examples of applications include the State-of

Environment (SOE) reporting (Australia, Canada and New Zealand) and the set of sustainability indicators proposed by the United Nations Commission on Sustainable Development (CSD). The latter has been tested in selected developed and developing countries (Hayati, Ranjbar, & Karami, 2011).

In effect, indicators become a policy instrument to exert peer pressure among nations to perform better. The OECD has developed a common framework called "Driving force State Response" (DSR) to help in developing indicators. Driving force indicators refer to the factors that cause changes in farm management practices and inputs use. State indicators show the effect of agriculture on the environment such as soil, water, air, biodiversity, habitat and landscape. Response indicators refer to the actions that are taken in response to the changing state of environment. Using the DSR framework, OECD (1997) identified 39 indicators of issues such as farm financial resources, farm management, nutrient use, pesticide use, water use, soil quality, water quality, land conservation, greenhouse gases, biodiversity, landscape, wildlife habitats, and farm's contextual information, including socioeconomic background, land-use, and output. Similarly, the British Government suggested 34 indicators under 13 themes such as nutrient losses to fresh water, soil P levels, nutrient management practices, ammonia emissions, greenhouse gas emissions, pesticide use, water use, soil protection, and agricultural land resource, conservation value of agricultural land, environmental management systems, rural economy and energy (Hayati, Ranjbar, & Karami, 2011).

Most of the indicators mentioned above are suitable to evaluate agricultural sustainability at aggregate level. They cannot, however, be used to assess sustainability at the farm level, although individual farmers take the major decision in land-use including mode of use and choice of technology (Webster, 1999;cited in Hayati, Ranjbar, & Karami, 2011).

Sands and Podmore (2000) used environmentally sustainability index (ESI) as an indicator of assessing agricultural sustainability and applied it to farms in the United States. ESI represents a group of 15 sustainability sub-indices including soil depth, soil organic carbon, bulk density and depth of ground water. Tellarini and Caporali (2000) used the monetary value and energy value to compare the sustainability of two farms, high-inputs and low-inputs in Italy. Gowda and Jayaramaiah (1998) used nine indicators, namely integrated nutrient management, land productivity, integrated water management, integrated pest management, input self-sufficiency, crop yield security, input productivity, information self-reliance and family food sufficiency, to evaluate the sustainability of rice production in India (Hayati, Ranjbar, & Karami, 2011).

Reijntjes et al., (1992) identified a set of criteria under ecological, economic and social aspects of agricultural sustainability. Ecological criteria comprise the use of nutrients and organic materials, water, energy, and environmental effects, while economic criteria include farmers' livelihood systems, competition, factor productivity, and relative value of external inputs. Food security, building indigenous knowledge, and contribution to employment generation are social criteria (Rasul & Thapa 2003).

According to Hayati et al., (2006) scholars have classified the parameters in three groups (social, economic, and ecological). The social sustainability components include the education level of the household members, housing facilities, work study, nutritional/health status of the family members, improved decision making, improved the quality of rural life, living and working conditions, participation/social capital, and social equity. The economic parameters include average crop production, expenses for input, monetary income from outside the farm, monetary income from the farm, economic efficiency, profitability, the salaries paid to farm workers, employment opportunities, market availability, land ownership, and soil management. The ecological or environmental components include the following indicators: improved water resource management; usage of pesticides, herbicides, and fungicides; usage of animal/organic manures; usage of green manures; physical input and efficient use of inputs; physical yield; crop diversification; use of alternative crop; use of fallow system; crop rotation; cropping pattern; trend of change in climate conditions; use of chemical fertilizer; conservational tillage (no/minimum tillage); control erosion; microbial biomass with in the soil; energy; cover crop/mulch; depth of ground water; protein level of crops; and integrated pest management.

The first challenge in measuring production sustainability is to define the scope in conceptual terms. The conceptual issues of sustainability are reflected in its measurement. As sustainability requires the reconciliation of environmental features, social equity and economic demands, these three aspects can be the starting point for further research. Each of the three aspects can be presented as a function of their own phenomena. Studies on measuring agriculture sustainability are mostly partial in terms of Geographical zones and products (e.g. Hatai and Sen, 2008, Sands and Podmore, 2000; Koeijer et al., 2002; Gomez- Limon, 2010).

There is no common viewpoint among scholars about its dimensions (David, 1989; Webster, 1999). To some extent, what is defined as sustainable depends on the perspectives of the analysts (Webster, 1999). Ikerd (1993) indicated that the precise measurement of sustainability is impossible as it is site-specific and a dynamic concept. Nonetheless, various parameters for measuring agricultural sustainability have been proposed (Shiferaw, Prasanna, Hellin, & Banziger, 2011). At the farm level, Taylor et al. (1993) constructed sustainability index using 85 sample agricultural producers in Malaysia with point scored under the headings of insect control, disease control, weed control, soil fertility maintenance and soil erosion control (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

In determining production sustainability, environmental impact analysis should be done for a variety of farming systems. As such, organic farming, chemical based fertilization farming, conventional agriculture, monoculture system, integrated farming, farming with specific indigenous method, among others. all have been the subject of agro-ecological research. Previous impact evaluation studies also addressed farming practices such as seeding technology, fertilizer application, pesticide use, tilling practice, and irrigation management. It is presumed that the evaluation on the basis of both farm production practices and the farming system would work effectively when analysing impacts at the local scale (Van der Werf and Petit, 2002). Particularly for the farm level studies, evaluation of the environmental impacts on the basis of farmers' perception is also considered as equally important (Rasul & Thapa, 2003).

For a given 'farming system', it is the farmer, who is exercising 'production practices' and generating environmental impacts, and hence is experiencing resource extraction and pollution problems. This study, therefore, emphasises on considering farmers' 'perception' of agro-environmental attributes in impact indicator accounting procedure. It is hypothesized that the farmers' perception, measured by obtaining their opinion on the intensity of the environmental impacts, has a considerable role to play in the analysis of agro-environmental sustainability. Figure 1 shows an outline of the proposed farm-level environmental impact assessment approach that includes the components of production practices, farming system and farmers' perception in a composite way.

Evaluation strategies enable the determination of the sustainability of systems under investigation. They are based on the previously characterised sustainability perception, goal definitions and selected indicators or indicator sets. The evaluation process represents one of the most delicate parts of the concept. First, evaluation ultimately depends on normative options concerning setting of goals, selection of systems of concern and deduction of threshold values or ranges of tolerance (Finnveden 1997). Second, the evaluation of systems based on sets of single indicators ultimately remains inadequate since systemic sustainability represents 'more than the sum of the parts. Two strategies of sustainability evaluation may be distinguished – absolute and relative strategies

Absolute evaluation procedures exclusively investigate indicators and corresponding data derived from one single system. Hence, validation is based on a comparison with previously defined margins of tolerance or distinct threshold values for each selected indicator (Mitchell & McDonald 1995). These limits are determined either by estimation, e.g. resulting from expert interviews or referring to socio-political postulates for the reduction of emissions or by scientific deduction, e.g. elabouration of critical loads/levels based on eco-toxicological experiments. Therefore, absolute evaluation assesses distinct datasets e.g. the phosphorus content of the soil compared to the maximum tolerable content. This transparent presentation of results permits end-users to verify the assessment and if necessary to adapt the presented data to alternative threshold values.

Relative evaluation procedures are established on a comparison of different systems among themselves or with selected reference systems. Due to this comparative assessment of systems, there is no need to define distinct margins of tolerance or threshold values. Frequently the results of a relative evaluation are presented as normative point scores

Measurement of Production Sustainability

Measuring sustainability with indicators and their aggregation into indices is quite common method used by researchers. For example, Hatai and Sen (2008) have analysed the usefulness of highly aggregated Sustainable Livelihood Security (SLS) Index of agricultural sustainability in thirty districts of Orissa. SLS index was comprised of three indices: ecological security index, efficiency index, and index of social justice. The research has espoused that lack of governance and depletion of natural resources as well as rapid increase in population represent threat to the ecological balance and economic and social state of the districts. Furthermore, big differences among the farming systems of districts, according to the individual aspects of sustainability imply a reallocation of agricultural investments.

Likewise, Sand and Podmore (2000), presented the design and development of environmental sustainability index (ESI) for agricultural systems and confirmed its efficacy in practice. They used 15 indicators on the lower level, which refer to two dimensions of the agricultural system (i) soil fertility and access to groundwater, and (ii) the possibility of environmental degradation. Furthermore, Gomez-Limon and Jose (2010), conducted an empirical evaluation of sustainability with composite indicators for two agricultural systems: the area of Castilla Leon with a large quantity of rain and the river Duero Valley countryside with irrigation. The methodology is based on calculation of 16 sustainability indicators and their aggregation into nine sustainability indices covering the three components (economic, social and environmental).

The sustainability at the farm level was assessed by van der Werf and Petit (2002), using 12 indicators and 26 objectives. Vecchione (2010) has also formulated agricultural production sustainability index (ASI) and has tested it on the agricultural area Alta Val d'Agri in Italy. The model on measuring agricultural sustainability combines the analysis based on geographic information system (GIS) and multi- criteria decision analysis (MCDA). Vecchione used 18 agricultural indicators that are allocated into three sustainability dimensions. Indicators are normalized with "fuzzy logic" function using weights, which are assigned by analytic hierarchy process (AHP), and aggregated.

In addition, Walter and Stuetzel (2009), conducted sustainability study for Northwest Germany by using standardization process in which indicators are first normalized according to their contribution to sustainability, and then they are corrected by a factor that describes the significance of this impact in terms of exceeding the threshold. The process is conceptually similar to Life Cycle Assessment (LCA), which is impact analysis and evaluation process that assesses the individual standardized indicators in terms of sustainability. The authors tested two types of weights and found that their effect is relatively small, compared with the effect of standardization itself.

Effects of Production Sustainability

The summary of findings from a global literature review on yield effects of the adoption of production sustainability practices like the use of cover crops is reported to lead to higher yields due to decreased on-farm erosion and nutrient leaching, and reduced grain losses due to pest attacks. For example Kaumbutho and Kienzle (2007) showed that maize yield increased from 1.2 to 2.0 tonnes per hectare in Kenya with the use of mucuna (Velvet Bean) cover crop. Altieri (2001) reported that maize yields in Brazil increased by 198-246% with the use of cover crops. Crop rotations and intercropping designed to ensure differential nutrient uptake and use e.g. between crops, such as millet and sorghum and Nitrogen-fixing crops, such as groundnuts, beans and cowpeas will enhance soil fertility, reduce reliance on chemical fertilizers, and enrich nutrient supply to subsequent crops (Conant, 2010), leading to increased crop yields (Woodfine, 2009).

For example, Hine, Peacock, and Pretty (2008) showed that in the North Rift and western regions of Kenya maize yields increased to 3,414 kg/ha (71% increase in yields) and bean yields to 258 kg/ha (158% increase in yields); Parrot and Marsden (2002) report that, in Brazil, intercropping maize with legumes led to increases in both grain yield and total nitrogen content by 100%. Further, Wang, Jin, Bao, Li, and Zhao, (2014), reported that both grain yields and nutrient acquisition were significantly greater in all four intercropping systems than corresponding monocropping over two years in the Gansu Province of northwest China.

Increased crop yields after a fallow period have been widely reported (Agboola 1980; Hamid et al. 1984; Saleen & Otsyina 1986; Prinz 1987; Conant 2010), although the magnitude of yield increment after each successive fallow is variable, and bare fallow may increase soil erosion risk.

The use of improved crop varieties is expected to increase average yields because of the greater seed diversity of the same crop. For example the International Centre for Tropical Agriculture (CIAT, 2008) showed that the average yield increase due to the introduction of new bean varieties in seven African countries was 44% in

2004-2005, although the gains varied widely across countries, ranging from 2 percent in Malawi to 137 percent in western Kenya.

Adopting organic fertilization (compost and animal manure) is widely found to have positive effects on the yields. For example, Hine, Peacock, and Pretty (2008) showed that maize yields increased by 100 percent (from 2 to 4 t/ha) in Kenya; Parrot and Marsden (2002) showed that millet yields increased by 75-195 percent (from 0.3 to 0.6-1 t/ha) and groundnut by 100-200 percent (from 0.3 to 0.6-0.9 t/ha) in Senegal; and Scialabba and Hattam (2002) showed that potato yields increased by 250-375 percent (from 4 to 10-15 t/ha) in Bolivia.

Altieri (2001) quotes several examples from Latin America where adoption of organic fertilization and composting led to increases in maize/wheat yields between 198-250% (Brazil, Guatemala and Honduras) and in coffee yield by 140% (in Mexico); Edwards (2000) showed that in the Tigray province of Ethiopia, composting led to yield increases compared to chemically fertilized plots: barley (+9%), wheat (+20%), maize (+7%), teff (+107%), and finger millet (+3%); Parrott and Marsden (2002), reports that farmers in Bolivia increased potato yields by 20 percent using organic fertilizers (Branca, McCarthy, Lipper, & Jolejole, 2011)

Also, enhancing inputs of nitrogen through nitrogen-fixing plants that are not harvested (green manure) is key to maximizing production and ensuring long- term sustainability of agricultural systems (Fageria, 2007). For example, Kwesiga et. al., (2003) showed that in Zambia, including *Sesbania sesban* (an indigenous nitrogen-fixing tree) fallow in rotation led to increases in yields for maize with respect to continuous cropping. Maize yields increased from 6.75 to 7.16 and 7.57 t/ha following 1, 2 and 3 years fallow, showing that short leguminous fallow rotations of 1-3 years have the potential to increase maize yields even without fertilizers, thanks to the nitrogen-fixation capacity and mineralization of the belowground root system. Increasing the proportion of nutrients retained in the soil – e.g. through mulching and limiting nutrient leaching – is also expected to have positive effects on crop yields (Conant, 2010; Silvertown et al., 2006). For example, Lal (1987) reported yield increases by incorporating residue mulch of rice husks (about 6 t/ha) on different crops from 3.0 to 3.7 tonnes per hectare on maize, 0.6 to 1.1 tonnes per hectare on cowpea, 0.6 to 0.8 tonnes per hectare on soybean, 16.4 to 28.3 tonnes per hectare on cassava and 10.7 to 17.9 tonnes per hectare on yam. Also, soil water contents are generally higher under mulch cover (Barros & Hanks, 1993; Scopel et al., 2004).

Tillage systems – which adopt no-tillage, minimum tillage and crop residue management provide opportunities for increasing soil water retention. Therefore, crop yields are often higher than under conventional tillage (Derpsch & Friedrich 2009), especially in semi-arid and dry sub-humid agroecosystems. For example, substantial increases in rain-use efficiency with implementation of conservation tillage practices in sub-Saharan Africa are reported by Rockstrom et al. (2009). Studies examining maize production in semi-arid Mexico produced similar results (Scopel et al., 2005). Also, in semi-arid areas, no-tillage benefits seem to be higher on severely degraded soils because of low organic matter content and poor physical conditions (Acharya et al., 1998).

There is also evidence of yield and soil improvements from humid tropical and temperate agroecosystems (e.g. Rasmussen, 1999; Diaz-Zorita et al., 2002; Bronick and Lal 2005), where primarily minimum and zero-tillage practices are applied. In semi-arid sub-Saharan Africa, documented success with minimum tillage practices is limited and scattered, largely in relation to certain development projects, even though significant success has been reported from commercial farms (Oldreive, 1993).

Conservation farming success in Africa remains concentrated to more humid environments where many studies report positive effects on crop yields compared to traditional tillage management: Hine, Peacock, and Pretty (2008) report increases in maize yields (+34%) and soya (+ 11%) in Argentina; Hine, Peacock, and Pretty (2008) record increases in yields of maize (+67%, from 3 to 5t/ha) in ten years and soya (+68%, from 2.8 to 4.7 t/ha) in Brazil (Paraná and Rio Grande do Sul) and again maize (+ 47%), soya (+83%), and wheat (+82%) in Brazil (Santa Caterina).

Proper water management can help capture more rainfall (Vohland & Barry 2009), making more water available to crops, and using water more efficiently (Rockstrom & Barron 2007), which are crucially important for increased agricultural production (Conant, 2010; Rockstrom et al., 2010). Bunds/Zai and Tied Ridge Systems generate higher yields, particularly where increased soil moisture is a key constraint (Lal 1987). Terraces and contour farming practices can increase yields due to reduced soil and water erosion and increased soil quality. Altieri (2001) showed that restoration of Incan terraces has led to 150 percent increase in a range of upland crops; Shively (1999) finds that contour hedgerows can improve maize yields up to 15 percent compared with conventional practices on hillside farms in the Philippines; Dutilly-Diane et al. (2003) reported an increase millet yields from 150-300 to 400 kg/ha (poor rainfall) and 700-1,000 kg/ha (good rainfall) in Burkina Faso; and from 130 to 480 kg/ha in Niger but also note that bunds lead to increased yields in the low and medium-rainfall areas, but lower yields in the high rainfall area (which had exceptionally high rainfall the year of the survey).

Posthumus (2005) showed that in Peru yields obtained with bench terraces are higher than yields without terraces for maize in Pachuca (640 versus 408 Kg/ha) and for potato in Piuray Ccorimarca (3,933 versus 850 kg/ha). However, it is also found that the yield increase is nullified by the amount of area lost (20%) due to the terracing, which makes it necessary to fully exploit the terraces (e.g. cultivation of a second crop during the dry season, use of organic fertilizers, or use of irrigation) in order to counterbalance the production loss (Posthumus, 2005; Branca, McCarthy, Lipper, & Jolejole, 2011).

Water harvesting techniques (e.g. run-off collection techniques, water storage tank construction, use of devices for lifting and conveying water, micro catchment water conservation with film mulching) also increase yields: Parrott and Marsden (2002) showed that water harvesting in Senegal changes the yields of millet and peanuts by 75-195 percent and 75-165 percent respectively and that water conservation techniques resulted in 50 percent increase in productivity in eastern and central Kenya (Branca, McCarthy, Lipper, & Jolejole, 2011).

Agroforestry refers to land use practices in which woody perennials are deliberately integrated with agricultural crops, varying from very simple and sparse to very complex and dense systems. It embraces a wide range of practices (e.g. farming with trees on contours, intercropping, multiple cropping, bush and tree fallows, establishing shelter belts and riparian zones/buffer strips with woody species etc.) which can improve land productivity providing a favourable micro-climate, permanent cover, improved soil structure and organic carbon content, increased infiltration and enhanced fertility (WOCAT, 2011) reducing the need for mineral fertilizers (Schroth & Sinclair, 2003; Garrity, 2002). For example, Parrott and Marsdem (2002) reports yield increases of 175 percent on farms in Nepal; Verchot et at. (2007) reported an increase in maize yields from 0.7 to 1.5-2t/ha in Malawi. Use of live fences is also expected to increase yields (e.g. Ellis-Jones and Mason (1999) reports increased from 13.5 to 31.7t/ha of cassava yields) although results are controversial (Branca, McCarthy, Lipper, & Jolejole, 2011).

It is worth noting that sustainable livestock management practices on grasslands can have a positive impact on food security by livestock yields. Research has documented that improved pasture management by improving vegetation community structure (e.g. seeding fodder grasses or legumes with higher productivity and deeper roots) can lead to higher livestock yields due to greater availability of better quality forage with potential increased returns per unit of livestock (Sleugh et al., 2000; Hussain & Durrani, 2007). Adopting improved grazing management (stocking rate management, rotational grazing, and enclosures to allow degraded pasture to recuperate) has also the potential to increase livestock yields. For example, Derner et al. (2008) showed that average daily gains (kg/head/day) decreased with increasing stocking rate and grazing pressure: heavy stocking rates reduced average daily gain by 16% and 12% compared to light and moderate stocking rates, respectively. Haan (2007) reported that grazing cattle return to the pasture over 80% of Phosphorus and other nutrients consumed in forage, and these nutrients become available to support forage growth and livestock productivity. However, as noted above, for the most part there is very limited evidence on changes in livestock productivity from various management options, and even the extent to which there is documented overgrazing particularly in semi-arid regions (Branca, McCarthy, Lipper, & Jolejole, 2011).

Constraints to Agricultural Production Sustainability

As in any other part of the world, agriculture in Africa is dependent on constraints and limitations imposed by the policy regulations and natural resource base. Foremost among these constraints are those related to land availability, land fertility, and access to water. Traditionally, African countries have faced fewer land constraints because of their comparatively low population density, but many rural areas may be facing rapidly rising population density (Badlane & Collins, 2015; Jayne, Chamberlin, & Muyang, 2012).

Water constraints similarly limit production in many areas. Almost all agricultural productions in Africa are rain-fed. Barely 4 percent of the cultivated area in Africa south of the Sahara (SSA) was equipped for irrigation in 2005, compared with 18 percent globally (Svendsen, Ewing, & Msangi, 2009). Rainfall, which varies dramatically across Africa, often limits agricultural production during dry seasons and droughts (Xie, You, Wielgosz, & Ringler, 2014). Soil degradation is another constraint that tends to worsen with increasing population density and associated shortened fallow periods in many areas.

The risk associated with agricultural production is pervasive and have adverse implications on farming activities. These include climatic risk (erratic rainfalls, higher temperatures, and low humidity) affecting yields considerably and evident in the proliferation of pest and disease conditions. In the absence of insurance against such risks, they result in negative consequences on agriculture. Furthermore, farmers are confronted with challenges regarding the use of marginal lands due to scarcity of cultivable lands, infrastructure constraints: poor roads networks, inadequate and nonexistence of storage facilities, availability and cost of agricultural inputs and cost of agricultural labour (Gulati *et al.*, 2005).

Difficulty in accessing credit, high transaction cost associated with accessing inputs and marketing facilities (challenges and opportunities), are also persistent. Therefore, farmers who are normally risk averse eventually find ways to eschew these effects (Torkamani & Haji-Rahimi, 2010). Farm households manage risk by engaging in enterprises that provide sustainable security (in terms of food and income) even if such activities provide lower income by preferring to use established techniques of production (Nyikal & Kosura, 2005). They tend to be inclined towards self-insurance strategies such as diversification and social mechanisms (Korir, 2011) to address their income and food security needs. Despite these constraints, Africa has huge potential in maize production. An estimated 88 million hectares of land is suited to maize that is not presently cultivated, even after excluding protected and forested areas (World Bank, 2010). This is almost three times the area currently sown and over half of the available land suited to maize production globally (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

As argued by Menker (2016), the world's farmers are getting older, with their average age reaching record highs around the world. In spite of the fact that majority of the population in Africa is very young, with about 60 percent of the population under 24 years old, the average age of farmers in Africa is 60 years or beyond. As farmer age demographics push higher and higher, there is a general concern among stakeholders about the risk of not having enough human capital working in the farm sector in the near future if the current generation of farmers will retire. The most calamitous predictions made by Menker (2016) are that the farm sector will be deficient of its economic potential and there is eminent situation of not having enough farmers to feed the world by a single generation.

A peculiar condition accounting for aging farmers in sub-Saharan Africa is the rapid rate of urbanisation. From 1961 to 2015, the percentage of people living in urban areas in sub-Saharan Africa more than doubled, from 14.6 percent to 37.7 percent. Young people in sub-Saharan Africa are experiencing higher barriers to entry into farming than they were a generation ago. But rather than access to capital equipment, the largest barrier is access to land.

Populations have grown rapidly, yet land available for agriculture has not kept up. From 1960 to 2015, the population of sub-Saharan Africa has more than quadrupled, growing from 228 million to over 1 billion. In a country where most farmland is already occupied, young people are entering the workforce more quickly than farmers are retiring. African urbanization is therefore driven both by attractive opportunities in burgeoning cities as well as a dearth of opportunities for young people in rural areas (Menker, 2016).

Global Productivity Growth, Consumption Patterns and Trends of Maize

Maize area and production at the global level have shown dramatic changes over the past 50 years. Between 1961 and 2010, the global maize area increased by 50 percent, that is from about 100 million to more than 150 million hectares. Significantly, much of the area growth occurred in the developing countries where cultivated area has almost doubled from 60 million hectares in 1961 to about 112 million hectares in 2010. Production and productivity has also registered a much faster growth in the developing regions. Production increased by more than five folds from about 75 million metric tonnes to about 405 million metric tonnes during the same period. In the developed economies, area of production has changed very little over time (39 million hectares in 1961 to 41 million hectares in 2010). However, the production of maize has increased three-fold, indicative of an impressive growth in productivity over the 50 year period. This picture among the developed and developing countries indicates a dramatic growth in maize production at the global level – registering almost a four-fold increase from 200 million metric tonnes in 1961 to 765 million metric tonnes in 2010 (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

These figures, however, conceal significant variability among regions and countries in terms of area, yield and production responses over the past half century. For example, despite the tripling of the maize area, yield has not shown significant changes in sub-Saharan Africa. Excluding South Africa, maize yields in sub-Saharan Africa only increased by about 40% over this period (from about 0.9 t/ha to 1.5 t/ha). Variability of yield for maize is also extremely high in this region. Over the past 10 years, the annual growth in area expansion is highest in West and Central Africa (3.26%), East Asia (3.13%) and Eastern Europe (3.98%) (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Although regional pooled data still hide a lot of information on intra-regional variation across countries, the variability of production and yield is very high for countries in Africa, South Asia, and Latin America as well as Eastern Europe. When complemented with market risks associated with poorly integrated domestic and regional markets, small-scale maize producers often face significant challenges in smoothing consumption and income over time (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

The Role of Maize in Achieving Food Security

The importance of maize in ensuring food and nutritional security cannot be over emphasized. Millions of people in the developing world, especially in Africa and Latin America, depend on maize as their staple. The role of maize for human consumption, expressed in terms of the share of calories from all staple cereals, varies significantly across regions. This ranges from 61 percent in Mesoamerica, 45 percent in Eastern and Southern Africa (ESA), 29 percent in the Andean region (Bolivia, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela), 21 percent in West and Central Africa (WCA), to 4 percent in South Asia. The contribution of maize as a source of proteins from all the cereal staples is very similar to its contribution of calories. Its use as a source of food accounts for 25 percent and 15 percent of the total maize demand in the developing countries and globally, respectively (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

In sub-Saharan Africa, maize is mainly a food crop accounting for 73 percent and 64 percent of the total demand in ESA and WCA. In South Asia 46 percent is used as food mainly for poor households who cannot afford other staples such as rice and wheat. The demand for food is also high in Mesoamerica (44%), North Africa (39%) and the Andean region (36%) as well as South East Asia (29%). This makes maize particularly important to the poor in many developing regions of Africa, Latin America and Asia as a means of overcoming hunger and improving food security. Its high yields (relative to other cereals) make maize particularly attractive to famers in areas with land scarcity and high population pressure (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

As it was introduced to new cultures and new agro-ecologies, new varieties were selected to meet dietary preferences better and new uses were developed with adaptation to biophysical environments. The nearly complete change in the diets of tens of millions of Africans from traditional sorghum and millet to maize in less than two generations represents an almost unprecedented transformation in food production and consumption patterns (Byerlee & Heisey, 1997; Shiferaw, Prasanna, Hellin, & Banziger, 2011). Farmers in both sub-Saharan Africa and Mesoamerica generally grow maize as a food crop rather than as an industrial crop, although they often sell it for cash (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Maize is rich in vitamins A and E but lacks the lower B vitamins that are found in other grains like sorghum or wheat. It is also low in usable protein and its leucine blocks the human body's absorption of a vitamin called niacin whose absence can lead to protein deficiency (McCann, 2005). The development of quality protein maize (QPM) by CIMMYT has enhanced the nutritional value, especially through higher levels of lysine and tryptophan in the endosperm and better amino acid balance. The consumptions of the QPM varieties has shown significant improvement in growth and development of children in Africa (Gunaratna, De Groote, & McCabe, 2008; Shiferaw, Prasanna, Hellin, & Banziger, 2011).

In addition to the use of maize for human consumption, the demand for maize has significantly diversified from its use as a source of food to livestock feed, industrial processing, seed and other alternative uses. At the global level 63 percent of the maize demand is for livestock feed while in the developing countries this currently stands at around 56 percent. These aggregate figures obscure significant variation in alternative uses at the country level across the developing and the developed world. In the high income countries, 70 percent of maize is used as feed and only 3 percent for direct human consumption. By contrast, in sub-Saharan Africa outside of South Africa, more than two-thirds of maize is used as food and only about 18–20 percent as animal feed (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Maize is also an important component of feed for the meet industry, especially in Asia where maize consumption has soared, driven by the growing demand for maize as poultry and pig feed. Total meat consumption in seven major Asian countries (China, India, Indonesia, Nepal, Thailand, Philippines, Vietnam), mostly pork and poultry meat, rose from 20 million metric tonnes in 1980 to 77 million metric tonnes in 2000, (Wada, Feng, & Gulati, 2008). In the poultry industry maize accounts for most of the energy in the feed ration for broilers: broiler rations, on average, contain 60–65 percent maize, 28–30 percent soybean meal, and 2–3 percent oil. Overall maize use for feed in the seven major Asian countries has more than tripled from 29 million metric tonnes in 1980 to 109 million metric tonnes in 2000 (Wada, Feng, & Gulati, 2008). Worldwide demand for maize as livestock feed is growing at 6 percent per year, and is projected to be a major component of future demand (Shiferaw, Prasanna, Hellin, & Banziger, 2011). Sub-Saharan Africa has been described as self-sufficient due to the fact that South Africa produces to meet the short falls in other growing countries (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

The bulk of maize produced goes into food consumption and it is arguably the most important crop for food security. However, Ghana is not self-sufficient in the production of this staple crop. Maize demand is projected to grow at a compound annual growth of 2.6 (MiDA, 2010). Thus, it is important to increase productivity and overall production of the crops to meet the country's growing demand for maize and to improve overall food security. It is a crop deemed necessary when combating the problem of food insecurity.

Factors Influencing Maize Production

Maize is primarily grown as a rainfed crop in many developing countries including sub-Saharan Africa, Asia and Latin America. Under uncertain climatic conditions, this increases the risks associated with maize production. Depending on the climatic uncertainties, dependence on rainfall causes the year to year variation in maize yields and production (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

The main factor for the dramatic growth in production and yield response at the global level is the growth in demand for maize for both food and non-food uses. It is significantly higher than for other cereals (wheat and rice). In 2010, maize accounted for more than 40 percent of the global demand for the major cereals while wheat and rice accounted for 30 percent and 25 percent respectively. Much of the growth in maize demand originated from the developing regions where it has grown by more than six during the same period. Demand only grew by less than half of this rate in the high income economies (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Drought is the most important constraint to enhancing maize production and productivity in the tropical and subtropical regions. About a decade and half ago, before recognition of climate change, Heisey and Edmeades (1999) estimated that in sub-Saharan Africa roughly a quarter of the area of maize in the lowland tropics and 22% in the mid-altitude/subtropics were frequently under stress from drought. Soil fertility is probably an even more serious constraint in most maize growing environments in Africa, due to very low use of fertilizer and the demise of bush-fallow systems of soil fertility replenishment (Morris, Kelly, Kopicki, & Byerlee, 2007). Those farmers who are mostly affected by recurrent drought are likely not to invest in yield enhancing inputs but rather increase land holdings to low-input maize in the hope of ensuring household food security. Stabilizing and increasing productivity in the face of recurrent drought can promote cropping diversification, better management of soil fertility, and income generation (Shiferaw, Prasanna, Hellin, & Banziger, 2011). Nitrogen, either from chemical fertilizer or organic sources is one of the most important nutrients for crops. Due to the fact that most smallholder farmers cannot afford fertilizer, the use less than 10 kilograms per hectare of crop land. This reduces crop yield, thus negatively impacting income generation and food security of the farming households (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Conceptual Framework and Hypotheses Development

In the preceding section, the theoretical underpinnings of the research were discussed. In the following section the inclusion of the latent variable in the proposed research model development and associated hypotheses are justified and supported with relevant literature.

Constraining factors to maize production

Some researchers identified problems associated with adaptive capacity of farmers in their production activities to influence their perceptions of climate change and attitudes and practices of production sustainability. The lack of access to early warning information and the unreliability of seasonal forecast, insufficient access to inputs, lack of knowledge about adaptation options, lack of credit, lack of information about climate change, high cost of adaptation and insecure property rights are the main climate change adaptation constraints identified by researchers to be the factors constraining farmers adaptive capacity (Nhemachena & Hassan, 2007; Acquah, 2011; Acquah & Onumah, 2011; Sofoluwe, Tijani, & Baruwa, 2011; Gandure, Walker, & Botha, 2012; Sani & Chalchisa, 2016).

Other studies confirmed that information asymmetry, irregularities of extension services, inability to access available information and improved crop varieties/seeds, ineffectiveness of indigenous methods, lack of subsidies on planting materials, limited knowledge on adaptation measures, low institutional capacity, and absence of government policy on climate change were the main factors that prevented farmers from adapting to climate change impacts (Maddison, 2006; de Wit, 2006; Nzeadibe, Egbule, Chukwuone, & Agu, 2011; Sani & Chalchisa, 2016). In achieving food security and production sustainability there is the need to fit these challenges within specific social and economic contexts of different agricultural systems (Horlings & Marsden, 2011). These challenges, processes and outcomes will also vary across agricultural sectors (Pretty & Bharucha, 2014). In line with the arguments above, this study posits that:

H_1: The constraining factors will increase perceived climate change effects on the Maize farming activities

H_2: The constraining factors affect climate change response strategies adopted by the Maize farming households

H_3: The constraining factors will impinge on farmers' attitudes towards sustainable agricultural practices

H_4: The constraining factors affect livelihood diversification of the maize-farming households

H_5: The constraining factors prevent maize farmers from practising sustainable maize production

H_6: The constraining factors will increase food insecurity levels of the Maize farming households

Climate change effects

Matters of climate change and variability have been given a lot of importance by researchers and scholars in diverse areas of expertise mainly due to its effects on the sustainability of food and livelihood security, and the entire agricultural industry. As reported by IPCC (2007), food production will increase at higher latitudes while low-lying regions, which are mostly in developing countries, will become more vulnerable to crop failures and reduction in yields. To avert the negative impacts on the sustainability of the agricultural sector, there is the need to underscore the deleterious effects. Frequency and severity of extreme climate events such as droughts and floods will have precarious consequences. This could increase the number of people at risk of hunger and livelihood security.

Food availability, which is one of the pillars of food security, is dependent on the state of the environment and the natural resource base (Hanson, 2013). The strategies for reducing climate risk is to diversify production and livelihood systems such as soil and water management measures, and plant protection measures to maintain adequate crop yields (Rudolf & Hermann, 2009; Apata et al., 2009). Sangotegbe, Odebode and Onikoyi (2012) reported that farmers are only able to put up adaptation strategies that are accessible and affordable. A positive and significant relationship was found between climate change and women's livelihoods, which implies that climate change impact positively on women's livelihoods whiles it adversely affects the men's (Vorsah, 2015). As a result, smallholder farmers adopt coping strategies to safeguard their livelihoods.

Stutley (2010) indicated that extreme temperature in Ghana was the source of low yields in the crop production, and similarly, Mendelsohn et al. (2006) contended that extreme temperatures and prolonged drought periods in Ghana were the major causes of low crop productivity. The changing rainfall pattern has been reported by Bello et al. (2012) to increase the incidence of pest, diseases, drought and flooding; this will eventually increase the possibility of food shortages and price increase, thus wiping out most of the gains made in reducing poverty that will be realized without climate change.

Smallholder farmers adopt coping strategies such as agronomic practices (which included early/late planting, early/late harvesting, intercropping, irrigation and agroforestry) in the face of droughts and floods (Vorsah, 2015). The long-term frequency and severity of extreme climate events could have serious consequences for food security, potentially causing reduced crop yield, crop failure and farmers having to grow a different variety of crops. Agriculture, as it is known, has the greatest need for adaptation.

Following the above debates or facts, the study posits that:

H_7: The perceived climate change effects would increase the number of climate change response strategies adopted by the Maize farming households

H_8: The perceived climate change effects would lead to negative attitudes of farmers towards sustainable agricultural practices

H_9: The perceived climate change effects would lead to livelihood diversification of the maize-farming households

H_{10}: The perceived climate change effects will reduce sustainable maize production practices of farming households

H_{11}: The perceived climate change effects would reduce food security among the maize-farming households

Livelihood diversification

The economy of Ghana is largely dependent on the agricultural sector. The small-scale farming dominates the agricultural sector and accounts for nearly all the total area under crop and more than 90 percent of crop output. The livelihoods of 84 percent of the citizens depend on various agricultural productions (Fikremarkos, 2012). However, farming as a primary source of income has failed to guarantee sufficient livelihood for most farming households in Sub-Sahara African countries (Babatunde, 2013). This is because the agricultural sector in the Sub-Saharan African countries is highly characterized by decreasing farm sizes, low levels of output per farm, and a high degree of subsistence farming (Jirstrom et al., 2011).

Agricultural activities in rural Ghana are also dominated by smallholders, the majority cultivating less than 0.5 hectare and producing mostly basic staples for the subsistence of their households (Arega et al., 2013). In view of this dependency on agriculture and the concomitant level of rural poverty, investigations on the nature of livelihood diversification also clearly reflect the desire to understand better whether promoting diversification offers potential for livelihood enhancement and poverty reduction (Deiniger & Okid, 2000). Thus, the diversity of rural households is an important feature of survival in rural areas (Belaineh, 2002). Similarly, Reta and Ali (2012) indicated that in rural Ethiopia, if there had not been other sources of income apart from agricultural production, the land scarcity by the farmers, coupled with agricultural risks, could not generate enough income to feed household members and households could not have been fulfilled.

Furthermore, livelihood diversification is believed to be a solution, and an effective strategy for the reduction of poverty and food insecurity in rural Ethiopia (Yenesew et al., 2015). Studying the effect of livelihood diversification on household by Gebreyesus (2016), total income was important since income diversification through enterprise diversification reduces the need for liquidity in a household. Livelihood diversification strategies have been meeting the gap of farming source of income by directly increasing households' income (Gebreyesus, 2016). The results of a study by Gebreyesus (2016), show some important findings about the effect of livelihood diversification on rural household income. Livelihood diversification has statistically strong and significant positive effect on the total household income. Owning higher number of livestock and larger size of farm land with better access to improved seed helps rural households significantly improve their farm income in particular and household total income in general. Rural households with higher household size and more diversification ability tend to diversify income sources (Gebreyesus, 2016). Absence of farm mechanization has increased the importance of farm family labour resulting in the higher family labour productivity and significant positive effect on farm household income. Thus, households can increase their income by diversifying their farm and non-farm activities.

According to Ojo et al., 2014, crop diversification on food crop output has been found to be positive and significant. This implies that a unit increase in the diversification index of these crops led to increase in the production of food crop by 0.98, hence increase in availability and accessibility of food. Saraswati et al., (2011) reported that crop diversification had positive and direct effect on crop outputs among arable crop farmers. The income from livelihood diversification will motivate farmers to purchase fertilizer and improved seed and relieves credit constraints to agricultural intensification among small farm size holders. Again, as farm households allocate the labour of the family members to livelihood diversification activities, it helps to smooth their annual consumption expenditure. These non/off-farm income sources may help to create job opportunity for large family size of the households in the study area (Apata, 2009).

Households try to stabilize their income by diversifying into livelihoods that are less susceptible to climate change and price variations (Alemu, 2012). In addition, lack of sufficient access to important farm requisites and assets could force households to look for additional or alternative sources of livelihoods (Gecho et al., 2014). Climate change challenges negatively affected rural livelihoods as well as their attainment of livelihoods outcomes such as increase in income and improve food security (Amikuzuno, 2013; Fosu-Mensah, 2013). Farmers' attitudes strongly favoured introduction of new crops, changes in crop varieties, and changes in planting times and disfavoured soil, land, and water management practices (Shikuku, Winowiecki, Twyman, Eitzinger, Perez, Mwongera & Läderach, 2017).

Again, Deressa et al. (2009), Sofoluwe et al. (2011), Tazeze et al. (2012) and Obayelu et al. (2014) also argued that the higher non-farm incomes and better approached resource (credit and information) households could afford the better or higher investment adaptation options for their farm practice. Following the above debates or facts on the correlates livelihood diversification, the study posits that:

H_{12}: Livelihood diversifications has positive causal relationship with climate change responses strategies adopted by the Maize farming households

H_{13}: Livelihood diversifications of the maize-farming households have positive causal relationship farmers' attitudes towards sustainable agriculture

H_{14}: Livelihood diversifications increase sustainable production practices of the maize farmers

H_{15}: Livelihood diversifications would increase food security of the maize-farming households.

Attitudes towards sustainable agricultural production

According to Campbell (1963), attitudes and their associated behaviours are inseparable aspects of the same latent disposition. Lagerkvist et al. (2015) explains, for example, how a farmer working hard towards the goal of improving soil fertility conditions can be anticipated to have a strong positive attitude to integrated soil fertility management (ISFM). In that context, the farmer carves out a set of ISFM behaviours consistent with their disposition (Lagerkvist et al., 2015). Similarly, a farmer with strongly expressed attitude towards increased resilience to climate risks can be expected to carve out a set of adaptation behaviours based on their disposition. Behaviours in that case are a transitively ordered set of means to implement different levels of attitudinal goals (Kaiser et al., 2010).

The findings by Zeweld, Huylenbroeck, Tesfay and Speelman (2017) reveal that attitudes and normative issues positively explain farmers' intentions to adopt sustainable production practices. Perceived control also has a positive significant effect on the intention to apply minimum tillage (Zeweld, et al., 2017) and so when the intention is formed, farmers are expected to carry out their intention when opportunities arise. Moreover, perceived usefulness, and perceived ease of operation of particular sustainability strategy are also significant predictors of farmers' attitudes (Zeweld, et al., 2017). Personal efficacy, training and perceived usefulness play significant roles in the decision to adopt sustainable practices and willingness to adopt seems to be limited by negative attitudes and by weak normative issues (Zeweld, et al., 2017).

The results of a study by Bagheri, Fami, Rezvanfar, Asadi and Yazdani (2008) show that farmers had good perception about sustainable technologies such as diversification and rotation, application of manure but in general, they preferred modern technologies to local ones. Farmers also perceived agrochemicals as the best means to combat against pests and to increase production but their perception of intangible impacts of modern technologies was weak. It was found that there was a relationship between the numbers of socio-economic factors (such as human capital factors, information sources use, extension participation and landholding size) and the perception towards selected sustainable agricultural technologies (Bagheri et al., 2008). According to Bagheri et al. (2008) farmers have negative perception toward some sustainable technologies, such as minimum tillage, reduced use of agrochemicals, mixed use of organic and chemical fertilizer, biologic and cultural control of pests. Farmers' attitudes strongly favoured introduction of new crops, changes in crop varieties, and changes in planting times however, their attitude tend to disfavour soil, land, and water management practices (Shikuku, Winowiecki, Twyman, Eitzinger, Perez, Mwongera & Läderach, 2017). Following the above debates or facts, the study therefore hypothesised that:

H_{16}: Maize farmers who have positive attitudes towards sustainable agricultural practices will adopt number of climate change responses strategies

H_{17}: Positive attitudes of farmers towards sustainable agricultural practices would lead to sustainable maize production practices

H_{18}: Positive attitudes of farmers towards sustainable agricultural practices increase food security of the Maize farming households

Climate change responses

Climate change, environmental degradation and stagnating yields threaten cereal production and world food security. The two-way relationship of climate change and agriculture is of great significance in particular to developing countries due to their large dependence on agricultural practice for livelihoods and their lack of infrastructure for adaptation when compared to developed countries (Yohannes, 2016). Agricultural activities are affected by climate change affects due to their direct dependence on climatic factors. On the other hand, with the help of the right farming practice agriculture could be the main solution for climate change by mitigation and adaptation response. Within the current and projected situation of climate change globally, long term solution is important by combining climate change adaptation and mitigation strategies in agricultural sector (Yohannes, 2016). Such practices could be organic agriculture, manure management, agroforestry practice and cover cropping.

It has been found by Uy, Limnirankul and Chaovanapoonphol (2015) that households who had better individual characteristics (male household head, ethnic majority, high maize experience, high education level and drought perception level) and higher socio-economic characteristics (no poverty; higher maize income and non-farm income; larger maize land area; far from central market and better accessing to credit and information sources, etc.) were more likely to adopt at least one adaptation option.

Deressa et al., (2009), Mudzonga (2011), Sahu and Mishra (2013) and Nhemachena et al. (2014) also found that the high level of farmer's education and experience increases the probability of uptake of adaptation options because these farmers have better knowledge and information on changes in climatic conditions. The study therefore proposed that:

H_{19}: Climate change responses strategies adopted by the maize-farming households would have positive causal relationship with sustainable maize production practices of the maize farmers

H_{20}: Climate change responses strategies adopted by the maize-farming households will improve food security of the maize-farming households.

Sustainable maize production

According to the American Society of Agronomy (January, 1989), sustainable agriculture is the one that, over the long term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fibre needs, is economically viable, and enhances the quality of life for farmers and society as a whole. Relying upon unsustainable agriculture will, in the long run, increase global food security. Studies involving small farms have indicated that sustainable agricultural practices can actually increase yield which have positive implication for food security. Estimated population increases suggest that the world population will reach nine billion by 2050, and 95 per cent of this growth will occur in the developing world, thereby increasing the long-term demand for food (Dodson et al., 2010).

One approach to achieving food security is to adopt the strong science-oriented or techno-centric concept of sustainable intensification (Godfray et al., 2010). This system attempts to achieve higher yields from the same acreage without damaging the environment. Supporters of this approach claim that substantial increases in crop yield can be provided through science and technology. Examples are crop improvement, more efficient use of water and fertilizers, the introduction of new non-chemical approaches to crop protection, the reduction of post-harvest losses and more sustainable livestock (Maye & Ilbery, 2011). However, it is debatable whether sustainable intensification can be achieved without significant increases in the use of chemical inputs. Yet, such high levels of pesticide usage reduce the ecological bases of sustainable farming, thus damaging prospects of achieving food security (Pretty & Bharucha, 2014).

Organic farming is a contrasting approach to conventional agriculture and can play significant role in adapting to and mitigating the impacts of climate change. However, its role in food security debates is far from clear (Kings & Ilbery, n.d.). Organic agriculture is a holistic production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, recognising that regional conditions require locally-adapted systems (Codex Alimentarius Commission, 1999). According to Kings and Ilbery (n.d.), water management is one of the key determinants of agricultural sustainability and therefore provision of adequate water supplies is an important requirement for the sustainability either organic or conventional farming agricultural systems in Ghana. It is, however, debatable which of these two farming systems is more sustainable, although it is assumed that conventional farming will contribute most to achieving future food security.

The closely related food security themes (that is, pesticides, fossil fuels, agricultural sustainability, GM crops and global climate change) are difficult to discuss in isolation as there are strong and quite complex connections between them (Kings & Ilbery, n.d.). Therefore, these can be considered a network of interrelated concepts; for instance, it is virtually impossible to examine the theme of food security without talking about agricultural sustainability (Laing, 2009). It is in line with the above arguments that the study proposed that:

H_{21}: Sustainable maize production practices of the maize farmers will lead to improvement in food security levels of the Maize farming households.

Based on the concepts and theoretical underpinnings reviewed in the literature, a schematic conceptual framework was developed in Figure 2 to illustrate the interrelationships among the key variables in the proposed research questions, models and corresponding hypotheses.

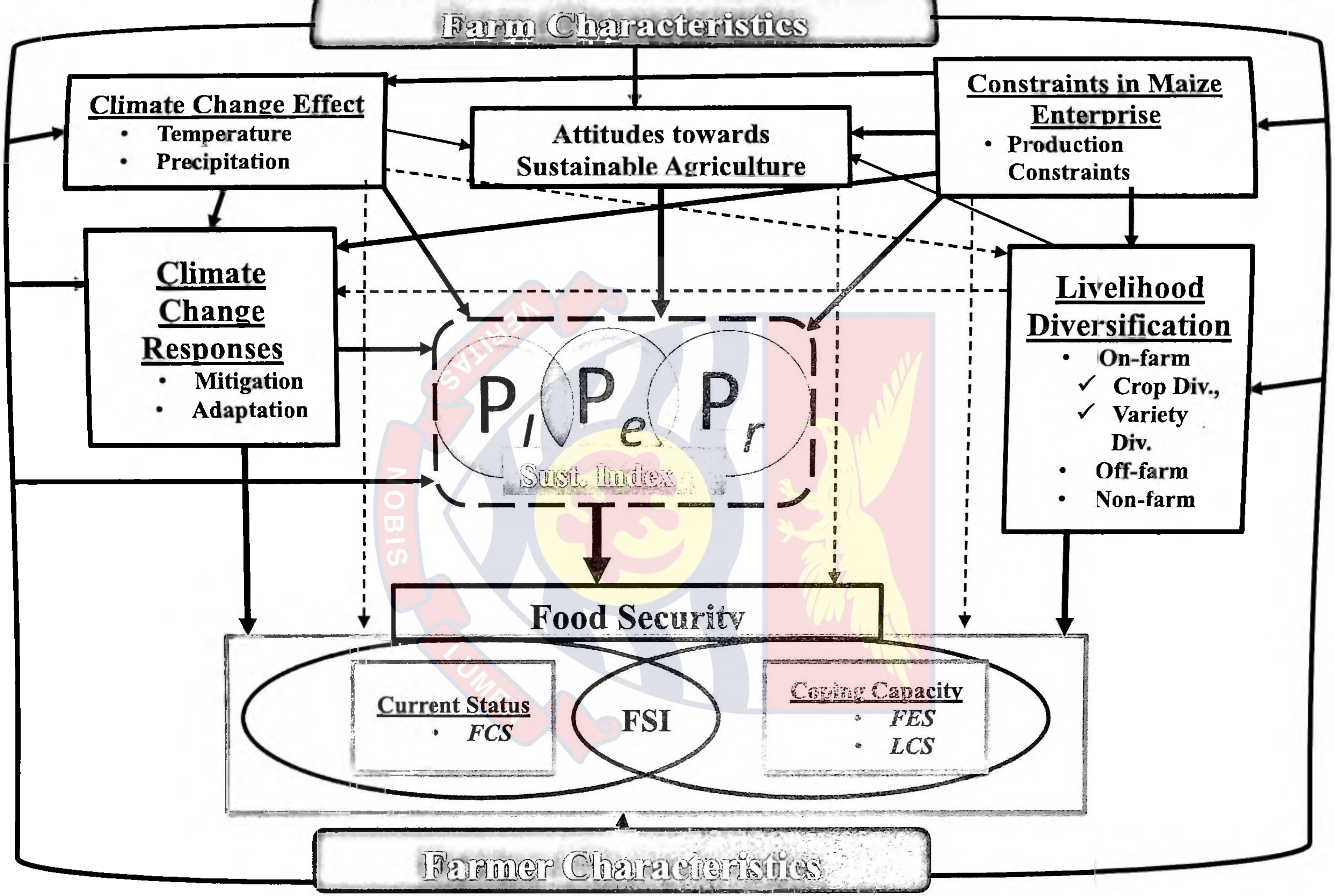

Figure 2: Schematic conceptual framework for the study
Source: Author's Construct (2018)

Summary

The literature review provided both theoretical and empirical evidences of the nexus of climate change responses, food security and sustainable agriculture. Within these, the concepts, dimensions and measurements of the key variables such as climate change, food security and production sustainability were delved into. Adaptive capacity in relation to climate shocks were also reviewed in addition to vulnerability to climate change impacts. Other related areas of food security such as the use of the consolidated approach for reporting indicators of food security (CARI) and current situations of global food security were also presented in the literature review. The growth, consumption patterns and trends in maize production from both the global and national scenario were also reviewed. Other major area of literature reviewed include constraints to maize production and postharvest handling, livelihood diversification and attitudes toward sustainable agriculture. Based on the relevant literature reviewed, a schematic conceptual model was formulated. The hypotheses were also developed using the structural equation modelling approach.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter presents the research methods and approaches employed for the study. It is organised into eight sections. The chapter begins with geographical setting of the study in the first section. The next section covers exposition on the research philosophy. It provides the various assumptions and criticisms of the positivists' philosophy and the need for the adoption of the pragmatists' philosophy, which adopts practical approach with varying emphases. The research design is discussed in the third section while the study population is described in the fourth section. Section five delve into sampling techniques adopted and sample size selection. Instrumentation and data collections procedures were also presents in section six and seven respectively. The last section presents the analytical techniques and tools used in the data processing and presentation of the findings.

Research Philosophy

Climate change is both natural and artificial process which all farmers experience throughout their farming business to the end their life. The process varies in different areas with regards to the associated effects on the individuals. Living with the related effects is becoming a sensitive issue to all and sundry; and what makes it worrying is the implication for food security, which is gradually taking toll on households in one way or the other. The farmers will continue to be the centrepiece as all of us depend and experience the outcomes of whatever output that comes out of the farming practices. It is against this backdrop that stakeholders in the society must take steps to assist the farmers to meet the necessary requirements for producing food on sustainable basis. The extent of assistance is so broad that the farmers stand to benefit better through support that would be derived through periodic scientific investigation. This study is therefore being steered by positivism and pragmatist philosophies.

Little (2007) outlines some core assumptions of positivism as they relate to both physical and social sciences. For instance, social science is identical in its logic to natural science. This is the naturalism referred to in the components of positivism. This implies that they have the same natural structure; and they describe the laws of nature. Hence, in the present study prevalence of climate change effects of the farming households is in focus. These effects can be available to challenge the achievement of food security of the farmers through sustainable agricultural practices; and thus have to be identified and if possible should be managed to reduce the negative effects on individual farmers and society.

In another assumption, science involves the search and explanation for general laws about empirical phenomena. This present study attempts to explain whether or not the farmers practice sustainable agriculture while aiming at assurance of household food security in the midst of climate change effects. Positivist scientists also focus attention on causal regularities rather than looking for real causal mechanisms. In this study, an attempt is made to find the relationship between food security and production sustainability.

Measurement and quantification is another assumption that has been emphasized by the positivists. This involves identifying a set of variables in research that can be observed, measured, and counted. Careful examination from the positivist's perspective would cover facts in the phenomena under investigation. Some of these facts in this study include the contribution of maize production to food security, and extent and prevalence of food insecurity among maize-farming households with different socio-economic classifications. Other vital facts that this study has addressed are the maize production and constraints and coping strategies adopted by households in reducing food insecurity and climate change effects. Some of these facts about the study are related to assumptions of positivism.

The above features of positivism do not however imply that the approach is free from criticisms. Whereas physical objects in the physical sciences can remain unchanged, human behaviour tends to be quite distinct in the sense that it can vary. Babbie (2007) observed that the positivistic social scientists sometimes erred in assuming that humans always act rationally. All human beings can never be the same. For instance, in the present study, chronological age and exposure to environmental factors can and are likely to influence many aspects of human decision making in life. A thorny issue here is who matters in the prevention of food insecurity and practicing sustainable agriculture, taking into considerations external influences of the climate. In relation to this conviction, scientists still search for better ways of understanding research. Hence Pragmatism philosophy comes to be used by scientists to enrich research basis.

Pragmatism, despite many variants, essentially means that individuals come to know the world through the practicality or usefulness of objects (or concepts). Pragmatists, as their name would suggest, adopt a practical approach, albeit with varying emphases. Although varied, common elements can be discerned in pragmatism and it is characterised, in most versions. In support of the criticisms against positivism, social science scholars such as Peirce, James, and Dewey have raised the following as some of the tenets of pragmatism (Hookway, 2016):

1. Pragmatism treats knowledge, concepts and values as true if they are useful. Pragmatists emphasise the practical function of knowledge as an instrument for adapting to reality and controlling it.
2. The pragmatists rejected the rationalist view that reality is static and fixed and preferred a view of a changing, dynamic reality.
3. Pragmatism is primarily empiricist and inductive, testing hypotheses, prioritising experiences, although not assuming that facts exist 'out there' waiting to be discovered. Facts are carved out of reality depending on people' (scientists') interests and purposes.
4. Pragmatists were content with probabilistic relationships rather than with deterministic ones.
5. Pragmatists, though, opposed the notion of passive objectivity. People cannot be neutral when observing the world; indeed they are suspicious of claims that one can observe independent of ones preconceptions.
6. Pragmatism adopts a relative approach: truth is modified as discoveries are made and is relative to the time and place and purpose of inquiry. This is not to say that we cannot know things rather that things have a variety of meanings, which are not directly apprehensible, rather an object acquires meaning through encounters with people, who define it in practice.
7. The function of thought is to guide action not provide timeless abstract truths; pragmatists interpret ideas as instruments and plans of action rather than as images of reality.

8. Thought is simply an instrument for supporting the life aims of the human organism. Pragmatists are not interested in knowledge for its own sake but knowledge as an aid to action. Ideas are suggestions and anticipations of possible conduct, hypotheses or forecasts of what will result from a given action, or ways of organising behaviour. The pragmatists objected to rationalist separation of mind and matter and regarded them as linked through human action.
9. Thought is grounded in practical reality and has no real metaphysical significance, pragmatists protest against speculation concerning questions that have no application and no verifiable answers. They are explicitly action-oriented and instrumentalist.
10. In its ethical aspect pragmatism holds that knowledge, which contributes to human values, is real. Not only is an idea true if it works it is also ‘good’. Thus, values play as essential a role in the choice of means employed in order to attain an end as they do in the choice of the end itself.
11. Pragmatists also advocated human rights and individual freedom.

Pragmatism is mixed methods research approach (use of both qualitative and quantitative methods) that is increasingly becoming popular in modern researches (Johnson & Onwuegbuzie, 2004; Molina-Azori & Cameron, 2010). Within social sciences, Iaydjiev (2013) contends that issues often arise in the world of human practice with new problems; and these are more appropriately addressed through the pragmatic approach. From the pragmatic philosophical perspective, food security and production sustainability and their implications turn out to be complex and sensitive issues to the farmers in achieving their livelihood. Whereas some people may wish to use whatever practices to get the maximum yield to improve their food security status with no or little regards to the future generations, others believe in the production system that will enable them continue to utilize the available resources in the future taking into consideration the economic, social and environmental implications of every actions they take. As occurrence of extreme climatic conditions rises steadily, many more people try to employ different production systems that will enable them achieve better results in the midst of the constraints associated with their livelihood activities. The prestige that is accorded best production systems soon takes a different form when external factors such as climate change leads to extreme drought or floods, diseases and pest outbreaks. This makes the farmers experience the effect of climate change differently. Essentially, this supports the pragmatic view calling for mixed methods for research on the sustainable agriculture practices. This study on climate change responses, food security and sustainable agriculture used the pragmatist approach as there were a few qualitative items.

Geographical Setting and the Choice of Volta Region for the Study

The Volta Region is located in the eastern part of Ghana and shares its eastern border with the Republic of Togo. The western border is shared with Greater Accra, Eastern and Brong Ahafo Regions while the northern border is shared with Northern Region. It is Ghana's fourth largest region and covers a surface area of about 20,572 km2. The region stretches from the shores of the Atlantic Ocean in the south, up to the Northern Region in the north. The 2010 Population and Housing Census recorded a total population of 2,118,252 inhabitants (1,019,398 men and 1,098,854 women) in the Volta Region. Out of the total population, about two-thirds are in the rural areas and are mainly involved in agricultural production (Ghana Statistical Service, 2012).

Ewe communities occupy most of the Region, with the exception of some areas in the Northern zone, which are largely inhabited by migrant groups from mainly Akan-speaking regions of Ghana such as the Central, Brong Ahafo, Eastern and Ashanti Regions. Farming is the dominant form of land use and the main source of income for most households in the Volta Region. This is related to the predominantly rural character of the region and fact that the region is well endowed with natural resources and fertile soils. Fishing is another important income-generating activity, especially for communities along the coastline and the Volta Lake. Trading activities can be observed throughout the region (Dancan & Brants, 2004).

By virtue of its geographical stretch and location, Volta Region has been described as a microcosm of Ghana. In addition to its cultural diversity, the region has total embodiment of all the major agro-ecological zones in the country. Being the only region that stretches from the south to the north of Ghana, Volta Region is characterised by almost all the agro-ecological zones in Ghana. The food production potentials of the agro-ecological zones have been recognized for years, where new agricultural technologies have been introduced.

The Volta Region has 25 administrative assemblies, comprising of districts and municipal assemblies, across the four main agro-ecological zones, which are distinguished by natural vegetation and influenced by climate and soil characteristics. The forest savannah transition and semi-deciduous forests zones make up the Middle Volta, allowing for two annual growing seasons (major and minor growing seasons). The Southern Volta is mainly characterised by coastal savannah zone, however, the upper part of the south has the feature of forest savannah transition and semi-deciduous forests. The Northern Volta also has the Guinea savannah as the main agro-ecological zone with the bottom part having forest savannah transition and semi-deciduous forest zones (Issaka, Buri, Tobita, Nakamura, & Owusu-Adjei, 2012).

Maize, as the main staple food for the majority people of the Volta Region, has the potential to grow on varied agro-ecologies. The dependence on maize in the region is a concern for food security, especially when other supplements for dietary diversity are limited. Annual rainfall in 2016 was 1,085mm showing a 10.6 percent reduction from 2015 (MoFA-SRID, 2017).

Research Design

This study adopted a cross-sectional survey design, which involves both qualitative and quantitative data collection to answer research questions on the interrelationships of climate change responses, food security and production sustainability among maize-farming households in the Volta Region of Ghana. Cross-sectional design is appropriate as data was collected from a section of the society (Maize farming households) to explain a particular problem. Zakour and Gillespie (2013) attest that this approach enables the researcher to compare different variables at the same time.

A concurrent nested mixed method research approach was mainly utilised by embedding qualitative into quantitative analysis since quantitative approach was emphasised predominantly the study. Creswell (2013) also asserted that the quantitative data yields numeric value and lends itself to statistical analysis; the qualitative item yields text data and it is often analysed in themes. In the present study, quantitative data (e.g. temperature, precipitation, yield, and efficiency), and qualitative data (e.g. anecdotal climate change effects on production, and food insecurity coping strategies) can be found in the instrument.

There were some contingency questions where participants were also requested to provide responses to open ended items and give reasons to some of their responses. For instance, maize farmers gave reasons for producing maize and their preference to the varieties they mainly produce over the years. These aspects of the study require qualitative approaches.

Target Population

The study was conducted among maize-farming households in the Volta Region of Ghana. The Volta Region had 888, 271 economically active labour force, comprising of 4181,193 males and 470,078 females. Out of this economically active population, 444,012 were into agriculture, forestry and fishing. In terms of sex, males were 238,649 while females were 205,363. There were 495,603 households in the Volta Region and out of this, 291,224 representing 58.8 percent are into agriculture. The number of household members engaged in agriculture and related activities stood at 599,276 comprising of 304,147 males and 295,129 females (MoFA, 2012).

The region has 5 Municipal and 20 Districts Assemblies. Those administrative assemblies that fall within the Northern zone are Krachi East, Krachi West, Krachi Nchumuru, Nkwanta North, Nkwanta South, Kadjebi and Jasikan; those that fall in the Middle zones are Biakoye, Hohoe, Kpando, Afadjato, South Dayi, North Dayi, Ho, Ho West, Adaklu and Agotime Ziope administrative assemblies; and the rest which are in the Southern zones are Keta, Ketu South, Ketu North, Akatsi North, Akatsi South, Central Tongu, South Tongu and North Tongu administrative assemblies. All the assemblies in the geographical zones are known to be involved in maize farming.

Sampling Technique and Sample Size Determination

Various methods have been recommended in accessing valid respondents in any study. The choice however depends on the population and design of the study among other things. The primary sample unit was the Maize farming household in the Volta Region of Ghana. The sampling was done in multiple phases to achieve higher precision in representativeness of the sample to the population. In a multiphase sampling, a combination of various sampling techniques and purposes are used in the sampling processes. Thus sample population changes at each phase of the research (Amoah & Eshun, 2015). In addition to achieving representativeness, multi-phase sampling procedure for the study was to minimise error and maintain a high confidence level (Sarantakos, 1993; Agresti & Finlay, 1997; Pearl, 2000; Cook & Garratt, 2005). The various phases of sampling are presented below:

Phase 1: a stratified sampling technique was employed to demarcate the region into the three main geographical zones of Southern, Middle and Northern. To get a large enough sample from each zone for individual locations analysis and to distribute the spread of the respondent households, 3 administrative assemblies were selected from each of the geographical zone. This sampling was done using simple random technique. Thus nine (9) administrative assemblies were selected for the study.

Phase 2: at least 5 communities were selected from each of the selected administrative assemblies. The selection of the number of communities was based on how wide-spread the administrative assemblies are in terms of geographical coverage and how important maize production is to the selected administrative assemblies.

Phase 3: simple random sampling was used to select 17 maize-farming households from lists with the help of staff from the Department of Agriculture in each administrative assembly.

Using a combined sampling strategy for the study is to optimize the chances of the chosen sample to be representative of a widely dispersed population (Gravetter & Forzano, 2009). The random selection of assemblies, communities and samples from each stratum or group was done to arrive at 765 sample size for the study. Thus, sampling 85 respondents from every selected administrative assembly was to ensure fair comparison among the groups.

Selecting a large number of respondents (85) from each administrative assembly is deemed appropriate so that location specific econometric analysis could also be done. Cohen, Manion and Morrison (2007), asserted that the number of variables researcher set out to control in their analysis and the types of statistical tests that they wish to make must inform their decisions about sample size. They added that, as a “rule of thumb”, one must be assured of having a minimum of 30 cases for each variable. As posited by Tabachnick and Fidell (2013), the sample size must be 8 times the number of predictors plus 50 more samples (i.e. $n \geq 50 + 8m$; where n = minimum sample size; and m = number of independent variable). Based on these assertions by these authors, a sample size of 765 is deemed suitable for the inferential analysis taking into account the number of independent variables.

Data Types and Source

Collecting good data is the foundation on which researchers gather evidence and make sense from it. Deciding what data is required when designing the research project is very crucial in gathering the right information from the start, and throughout the project. Both qualitative and quantitative data were collected mainly from primary sources. The primary data were collected from maize farmers across Volta Region.

Data Collection Instrument

The study was designed to use mixed method, hence interview schedule was used to collect both qualitative and quantitative data. The structured interview schedule was the main instrument used to collect the primary data for the study. The structured interview schedule was employed due to its relative advantage of flexibility, collection of in-depth information as well as provision of room for more explanations and applications (Kumar, 2005).

The researcher used items in related studies to develop the research instrument for the present study in order to provide for comparison of the findings with earlier studies. The structured interview schedule consisted of five main parts. The first part captured information on farm- and farmer-specific variables; techniques of production and organization of inputs. Also price data on output and the various inputs employed in production was collected. The last aspect of the first part was on constraints to maize production in the study area. The second part captured data on climate change and sustainable agricultural practices. The last session captured data on food security and coping strategies of the farmers.

The first part of the research instrument was measured using open-ended, partially closed-ended and closed-ended questions. Perceived climate change and climate change effect of the second part was measured using a four (4) response options with 1 representing increase, 2 = decrease, 3 = no change and 4 = fluctuating temperature or precipitation conditions. The second half of the second part was measured using a 10-point scaled items with 1 representing the highest level of disagreement and 10 representing the highest level of agreement on the indicators for sustainable agriculture. Actual practices of sustainable agriculture were measured using selected agronomic practices, and farm- and farmer-specific section variables in the first part of the instrument. The study used 1 to represent a sustainable production practice indicator and 0 to represent unsustainable production practice. These indicators were conglomerated to form a sustainable production practices index for each respondent. The level of agriculture sustainability was determined on the basis of data for 23 indicators, of which 6 measure economic aspect of sustainability, 10 environmental sustainability aspect and 7 social sustainability aspect.

The food security classification of each household was measured using the household food security index instruments adapted from the Consolidated Approach to Reporting Food Insecurity (CARI console) designed by WFP (2015). These indicators aim at estimating the actual number of food insecure households in a target population. The method is suitable for national and regional assessments, as well as more specific locations and households. Central to the approach is an explicit classification of households into four descriptive groups: food secure, marginally food secure, moderately food insecure, and severely food insecure. The indicators used to classify households into these food security classifications were the current food consumption (i.e. the food consumption score and the food energy shortfall); economic vulnerability (food expenditure share indicators); and, the livelihood coping strategies indicators. Each combination has been deemed to contain sufficient information for establishing the population's level of food insecurity (WFP, 2015).

The standard modules required to generate the console's indicators are included in Section G of the structured interview schedule (Appendix A). The indicators used for the two major domains of the CARI console were the food consumption score (FCS) for the current status (CS), and household expenditure share (HFES) and Livelihood coping strategy (LCS) for the coping capacity (CC). The consumption-based coping strategy items were also included in the research instrument though it was not used as a component of the CARI console for food security measurement.

The quality of the instrument was improved by subjecting it to thorough screening to give credence to the results. In view of this, peers read through the instrument for their inputs. Later authorities in the field and the research supervisors scrutinised the instrument for approval before it was taken out to the field for pre-testing. Results of the pre-test directed the final correction on the instrument. This measure was taken at least to ensure face and content validity of the instrument.

Validation and Pre-Testing of the Research Instrument

As a crucial guide in the survey methodology, this research is contrived towards unambiguous character. Once the survey started, the interview schedule remains unchanged, even if some questions can be better formulated. Therefore, preparing the final version of a interview schedule was very important; and this called for more attention during the development stage of the research instrument. Student researcher, supervisors and other experts in the field of the subject area from the University of Cape Coast determined the content validity of the structured interview schedule. Thus the quality of the instrument was improved by subjecting it to thorough screening to give credence to the results. In view of this, was given to colleague students to read through the instrument for their inputs. Later, authorities in the field and the researcher's supervisors scrutinised the instrument for approval before it was taken out to the field for pre-testing study.

Also, privileged witnesses and key-persons at all levels were consulted, including staff of the regional administrative council, experts, local entrepreneurs, farmer groups and people who have been active in farming in the region for a long time. Furthermore, there were discussions with extension workers including the directors of the Department of Food and Agriculture, the information services personnel and field officers, to have a first-hand information about extension services, production systems in the region, composition of farmers who are involved in the maize production, lists of the maize farmers and major areas that the production of maize can be found in the region.

This was done to check for consistency, validity, comments, and sought for other views. These comments and views were carefully noted and fully addressed in re-structuring the interview schedule for the main survey. This helped in highlighting the difficulties that were present in the interview schedule and gave ideal training to the field assistants (enumerators).

The survey enumerators were trained for three days prior to the pre-test survey to familiarize themselves with the research instrument as well as interview techniques through which they would collect the survey data. Bearing in mind that once the survey started the research instrument remains unchanged even if some questions can be better formulated, preparing the final version of the interview schedule was very crucial. This called for more attention during the testing stage since the research methodology is contrived towards unambiguous character. First, the structured interview schedule was tested within the enumerators to familiarise themselves further with the tool and to address or correct any issue and concerns enumerators may have with the tool. The enumerators then went to the field for the pre-test. Here, a version of the schedule was used in random communities in the Ho Municipality, which was not selected for the main survey.

The interview schedule was pre-tested on 60 respondents in the Ho Municipality, which is in the middle zone with Ho as the regional capital. Also, privileged witnesses and key-persons at all levels were consulted, including experts, local entrepreneurs, farmer groups and people who have been active in Maize farming in the municipality for a long time. Furthermore, there were discussions with extension agents including the Regional Management Information Systems Officer, The Regional Director of the Department of Food and Agriculture, Regional Meteorological Agency and field officers, to have a first-hand information about extension services, varieties of maize produced, composition of farmers who are involved in the maize production, lists of the maize farmers in the selected administrative assemblies in the region and major areas that the production of the maize can be found within the three geographical zones.

This was done to check for consistency, validity, comments, and sought for alternate views. These comments and views were carefully noted and fully addressed in the preparation of the final research instrument and conduct of the main survey. This helped in highlighting the difficulties that were present in the interview schedule and gave ideal training to the field research assistants (enumerators). More so, the pre-testing of the instrument was conducted to determine its reliability.

The pre-testing of the research instrument was conducted in March 2016 and it took one week for 6 enumerators with the student researcher to be able to complete 60 questionnaires. With the help of IBM SPSS version 21, Cronbach's alpha coefficient was used to determine the internal consistency of all the Likert-type while the Kuder-Richardson (20) reliability coefficient was conducted for dichotomous scales items

(Nunnelly, 1978; Pallant, 2013). This was done to check if items in various scale and sub-scales have the same underlying constructs. The reliability coefficients of the various constructs in the instrument are presented in Table 1.

The Cronbach's alpha reliability coefficient was conducted for attitudes towards sustainable agriculture, and constraints to maize production and postharvest activities. The Kuder-Richardson (20) reliability coefficient was used to determine the internal consistencies of climate change and climate change effect perceptions since the ratings were re-coded to dichotomized the scale (i.e. 1 = change/effect and 0 = no change/effect). The similar reliability was also conducted for sustainable agricultural practices and food security scales since they were measured in a binary scales (Pallant, 2013). The levels of food security, coping strategies during food insecurity, the climate change and agricultural sustainability perceptions, sustainable agricultural practices, constraints to maize production and postharvest indicated acceptable levels of reliability. Their levels of reliability were accepted since they were above the a priori benchmark of having a reliability co-efficient of at least 0.70 (Burns & Burns, 2008; Pallant, 2013). Those that could not meet the requirement were reconstructed by changing some of the wordings or eliminating the items that were reducing the reliability levels. The instrument was then accepted to be the final instrument for the study.

The results from the pre-test survey also helped to improve on validity of the instrument and to sharpen the skills of the enumerators. The field experience during the pre-testing of the instrument guided the research team on strategies to adopt for more efficient work in the main study. Some items were deleted since they were similar and appeared as repetitions and therefore confused the respondents.

Table 1: Reliability Co-efficient of the Research Instruments (n= 60)

Subscales	Number of Items	Type of reliability	Cronbach's alpha
Food security Index	3	Cronbach's	.758
Food consumption score	15	Cronbach's	.793
Food expenditure share	15	KR-20	.746
Livelihood-based coping strategy	10	KR-20	.829
Food-based coping strategy	12	KR-20	.846
Perceived climate change effects	16	KR-20	.704
Climate change responses	14	KR-20	.735
Attitudes towards Sustainable agricultural practices	14	Cronbach's	.718
Constraints to maize production	12	Cronbach's	.870
Constraints to postharvest activities in maize	7	Cronbach's	.902
Sustainable production practices	23	KR-20	705
Environmental sustainability	10	KR-20	.703
Social sustainability	7	KR-20	.719
Economic sustainability	6	KR-20	.724

Source: Field survey, Akaba (2018).

The number of items appeared to bother the respondents in the pre-test study thus regrouping was considered in the final instrument. In addition, the analysis of the field data guided the researcher in the final work on the instrument. The pre-test study also provided a clue on the most convenient time and place to meet the respondents for interaction either at home or in the farm, depending on the period of the day.

Data Collection Methods

The geographical spread of the region and cultural diversity of the subjects involved in this study were considered in recruiting six (6) field research assistants, in addition to the student researcher, who played a dual role of enumerator and supervisor. The supervision role was required to direct the work of the field research assistants on daily basis. These field assistants were graduates in agriculture and related programmes with social science backgrounds. As a requirement, an assistant must understand the issues under investigation, yet they were also taken through a thorough two (2) days training on the use of the instrument and data collection procedures.

These field research assistants for the study were trained together to ensure uniformity in their fieldwork. This group training was useful as they helped one another particularly in the interpretation of some of the items in the local languages. All field research assistants have a good command of the English language, and at least one of the major local languages (Ewe and/or Akan) to facilitate interaction with the respondents in order to obtain valid field data. These selected supporting staffs were preferred since they have some level of experiences and had an earlier chance in data collection in the study area. At the training, field research assistants were taken through the instrument thoroughly in order not to adulterate the instrument on the field. Other issues which were covered include community entry, establishment of rapport, ethical issues, and the process of data collection as a whole.

The interview schedule was administered to respondents by the researcher and six (6) trained enumerators, with assistance from the Department of Food and

Agriculture staff in each of the selected administrative assemblies where the data were collected. Personal interviews were conducted on a one-on-one basis with the sample maize farmers using the content-validated and pre-tested structured interview schedule. The data collection was done from 13th June, 2016 to 20th August, 2016. The main data collection process lasted for about 10 weeks; approximately one week in each of the selected district and about a day for mop up in each district.

Field research assistants explained every item in the research instrument thoroughly to the respondents (more especially to the illiterates) not only to avoid confusion but also to ensure that the correct information was obtained. Field assistants spent enough time to interpret the items for the illiterate farmers in particular. These participants were engaged between 45 to 65 minutes at each interview; the long duration in some cases was attributed to the differences in the participant's response to the items as some of the farmers were quite slow. The student researcher met with the field research assistants daily to inspect their work and ensure that they were on the right tract in the data collection and to ensure that the data collected would be valid to give credence to the results.

In the study, data were collected from 765 respondents in nine randomly selected districts. The one-on-one interaction offered high response rate in the study. Reduction in the number was attributed to some of the research instruments, which were rejected finally as a result of some inconsistencies detected during data cleaning. After the data cleaning and editing, 733 interview schedules were deemed valid for the study, giving a response rate of 95.8 percent. Fryrear (2015) recommends response rate of 80 percent and above for surveys of this kind.

As a good step to ensure quality of the study results, validation of data commenced right from the point and time of data collection. Each field research assistant searched thoroughly through each dataset to correct any inconsistency or anomaly from the respondents, particularly the few who responded to the instrument on their own. Furthermore, intermittent meetings were held with the research assistants to inspect the completed instruments. The outcome of the inspection led to some few corrections in the data collection, which helped to validate the data.

Data Processing

The mixed method employed for the study required both quantitative and qualitative data analysis with the former conspicuously dominating the analysis. In the quantitative analysis, computer programmes including IBM-SPSS version 21, Excel, and SmartPLS were used to analyse the data.

The data processing mainly begun with the data cleaning, editing and coding. Most of the items on the interview schedule were pre-coded before administration to facilitate easy entry and analysis. Open ended items were coded after the data collection exercise. Responses were scrutinised for completeness and accuracy on the field as a quality check on the data. Data omissions and mistakes detected were then corrected. Coded data on responses were fed into the computer based programmes after creation of templates in the variable viewer of the IBM-SPSS.

Data Analysis

Framework for data analysis

The analytical framework for each objective is presented in Table 3. It systematically presented the major variables and indicators for measuring the objectives, their levels of measurement, sources of data, how the data is collected and the analyitical techniques. The frameworks also presented the kind of mathematical operations, computational models and statistical distributions which were deemed appropriate in answering the research questions or the hypothesis of the study. It involves the production of a data matrix suitable for the various statistical analysis. This framework simplifies and presents a snapshot of the kind of analysis conducted in achieving each of the research objectives set for the study.

Table 2: Analytical framework for the study

Specific objectives	Variables/Major indicators	Level of measurement	Source of data	Method of data collection	Method of data analysis (framework & techniques)
Describe the state of maize production in the Volta Region	farmer specific characteristic: sex, age, education, main occupation, household size, farming experience, etc	Nominal ordinal ratio	individual farmers (primary)	survey using structured interview schedule observation using check lists	analytical description or scenario building: descriptive statistics: frequencies, percentages, cross-tabulations, means and standard deviation
	farm specific characteristic: sources of finance, access to credit, amount of credit, access to extension services, title to land, crop varieties, access to technical trainings, etc	Nominal ordinal ratio	individual farmers (primary)	survey using structured interview schedule observation using check lists	analytical description or scenario building: descriptive statistics: frequencies, percentages, cross-tabulations, means and standard deviation
	production techniques: land preparation method, crop varieties, planting system, weed control method, pest and disease control methods, harvesting, etc	Nominal ordinal interval	Individual farmers (primary)	survey using structured interview schedule observation using check lists	analytical description or scenario building: descriptive statistics: frequencies, percentages, means and standard deviation
	Perceived climatic effect on maize production Climate change response strategies adopted by maize farmers	Categorical, Interval	individual farmers (primary)	survey using structured interview schedule	descriptive statistics: frequencies, percentages, means and standard deviation, ANOVA, Correlations
	constraints to production: factors constraining input mobilization, production and crop protection	Interval	individual farmers (primary)	survey using structured interview schedule observation using check lists	Garrett ranking framework: percentage position of constraints

	Attitudes towards sustainable agriculture *Extent of agreement on sustainable agricultural practices*	Interval	Farmers (Primary)	survey using structured interview schedule	Kendall's Coefficients of concordance, Interval Standard Deviation from Mean, OLS, etc.
	Economic indicators of sustainable agriculture environmental indicators of sustainable agriculture social indicators of sustainable agriculture	Nominal ordinal interval ratio	individual farmers (primary)	survey using structured interview schedule observation using check lists	multi-criteria decision analysis framework multiple regression model techniques
Assess contribution of maize production to food security in the Volta Region	- Food consumption scores - food expenditure share - livelihood-based coping strategy - household food security index - farm specific characteristic - production constraints	Nominal Ordinal Interval Ratio	individual farmers (primary)	survey using structured interview schedule observation using check lists	Regression framework: Multiple linear Regression (OLS techniques)
To develop ideal model for improving sustainable maize production in the region	production techniques farmer and farm characteristics demand and supply situation maize production sustainability production constraints production efficiency food security	Nominal ordinal interval ratio	individual farmers (primary) GSS, RDA, DDA (Secondary)	survey using structured interview schedule observation using check lists	Structural Equation Modeling Partial Least Square technique

Source: Authors construct, Akaba (2018).

Techniques of analysis

The various techniques employed for data analysis are presented in the aspects of the study.

Attitudes towards sustainable agriculture

The grouping of respondents into the level of attitudes regarding sustainable agriculture was based on the Interval Standard Deviation from Mean (ISDM) as follows (Gangadharappa et al. 2007, Sadati, Fami, Asadi, & Sadati, 2010; Shiri, Hashemi, Asadi, & Motamedinia, 2012; Azman, D'Silva, Samah, Man, & Shaffril, 2013):

A= Very low: Min $\leq$ X $<$ Mean – St.d,

B = Low: Mean – St.d $\leq$ X $<$ Mean,

C = High: Mean $\leq$ X $<$ Mean + St.d,

D = Very high: Mean + St.d $\leq$ X $\leq$ Max

It should be noted that in the above formula, St.d imply the deviation from mean.

Attitude was categorised with score of 1 graded as negative attitude until 10 for positive attitude, to measure respondents' opinion on 13 items related to sustainable agriculture. In case of negative attitudinal statement, reverse score was assigned to each response. Based on the computed scores, the respondents were classified into four categories according to Sadati et al. (2010).

The Kendall's coefficient of concordance was used to establish the relative agreement of maize farmers on the importance of selected sustainable agricultural practices. Kendall and Smith (1939) provide a descriptive measure for which the concordance between rank orders within an individual rank structure can be assessed. This measure which is known as the Kendall's coefficient of concordance is a non-parametric statistic. It is a measure of agreement among several "judges" who assess a given set of objects. These "judges" could be variables or characters. It is used to identify a given set of indicators from the most sustainable to the least so as to measure the degree of agreement among respondents. In the study, the relative importance of the sustainable agricultural practices associated with maize production in the Volta Region was measured on a score of 1 (least sustainable) to 10 (most sustainable) in terms of magnitude. The rankings were then subjected to the Kendall's coefficient of concordance measure so as to know the degree of agreement of rankings by different maize farmers. The idea of this statistic is to find the sum of ranks for each practices rated and then examine variability of this sum. The analysis is a statistical procedure that is used to identify and rank a given practice from the most sustainable practice to the least sustainable practices, using numerals in the order 1, 2, 3, 4, …, m. The degree of concordance between these sustainable practices is then measured after the ranking. The total rank score computed is then used to estimate the Coefficient of Concordance (W), which measures the degree of agreement (concordance) in the rankings by the maize farmers.

After computing for the total rank score for each indicator, the indicator with the least score was interpreted as the least sustainable agricultural practice whereas the indicator with the highest score was ranked as the most sustainable agricultural production practice. Mathematically, it is expressed in equation (3.1) as:

$$W = \frac{12\left[\sum T^2 - \frac{\left(\sum T\right)^2}{n}\right]}{nm^2(n^2-1)} \tag{3.1}$$

Where (W) represents the coefficient of concordance which is defined as the ratio of the sum of squared deviations of rank totals from the average rank total to the maximum possible value of the sum of squared deviations of rank totals from the average rank total; T represents the sum of ranks for all indicators being ranked; m represents the number of maize farmers; n represents the number of indicators being ranked. The F distribution was used to test for the significance of the Kendall's coefficient of concordance (Tetteh, Adjetey & Abiriwie, 2011). Mathematically, the F-ratio is given as:

$$F = \left[(m-1)W/(1-W)\right] \tag{3.2}$$

From the above equation, the degree of freedom for the numerator is given as:

$$(n-1)-\left(2/m\right) \tag{3.3}$$

Likewise, the degree of freedom for the denominator is given as:

$$m-1\left[(n-1)-2/m\right] \tag{3.4}$$

On the other hand, one can compute the Kendall's coefficient of concordance by using the sum of squares of rank totals instead of the sum of squared deviations of rank totals from the average rank total. It can be expressed in the form given by Legendre (2005) as:

$$S = \frac{12\sum_{j=1}^{m} R_j^2}{m^2 n\left(n^2-1\right)} - 3\frac{n+1}{n-1} \tag{3.5}$$

The sum of all ranks in the observations, given as Kendall's W, picks the value of one when the ranks assigned by each maize farmer are the same as those assigned by other farmers (indicating total agreement among producers). On the other hand, if Kendall's W becomes zero, it implies that there is a total disagreement among the farmers. In other words, when perfect agreement exists between the values of the ranking variable, $W = 1$. When $W = 0$, then it means that there is maximum disagreement between the values of the ranking variable. Kendall's coefficient of concordance does not take negative values. It takes a value between zero and one ($0 \leq W \leq 1$). Here, the null hypothesis tested is that there is no agreement among maize farmers in the ranking of the sustainable agricultural practices indicators. The null hypothesis is rejected if the computed F-value exceeds the tabulated, showing that the respondents are in agreement with each other on the ranking of the constraints.

To assess the possible effects of the attitudes towards sustainable agriculture on sustainable maize production, a multiple regression model was adopted and this was specified as

$$S_i = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \ldots + \beta_n Z_n + \varepsilon \qquad (3.6)$$

where Si represents the sustainability index of individual maize farmers; Z1 … n represents the attitudes towards sustainable agriculture; ε represents the stochastic error term and the β represents the unknown parameters to be estimated which explain the marginal effect of the farmers attitudes towards sustainable agriculture on their sustainability indices.

Maize production sustainability

In assessing maize production sustainability, linear utility function has been extensively used. Three main indicators have been identified to aid in arriving at the level of sustainability of individual production systems. These indicators are environmental (e.g. fertilizer use, pesticides use measured in kg/ha, irrigation water consumption measured in rate of application/season and farm management practices measured as dummy); social (e.g. age of farmer measured in years, level of education measured in years, pluriactivity measured as dummy, family size and level of agricultural employment); and economic (e.g. productivity, farm financial resource and farm structure). In building the linear utility function, a multi-criteria decision analysis (MCDA) approach has been adopted. According to Dantsis, Douma, Giourg, Loumou and Polychronaki (2010), MCDA supports the structured evaluation of problems with multiple decision criteria. The approach is based on the multi-attribute value theory (MAVT) (Keeney & Raffia, 1976) which is able to aggregate different attributes. Firstly, in using this approach, an attribute tree that summarizes the sustainability indicators chosen was built. In this attribute tree, agricultural sustainability would be divided hierarchically into the three sustainability pillars (environmental, social and economic), then to the lower level criteria and finally to measurable attributes. The second stage would involve the creation of a cardinal value for each alternative decision, generated by the aggregated effect of all attributes.

Mathematically, the utility function or value of an alternative is usually expressed in equation (3.7) as follows:

$$v(x) = \sum_{i=1}^{n} w_i v_i(x_i) \tag{3.7}$$

where v stands for a single indicator value function over the consequence x_i, n is the number of indicators, w_i is the weighted of each indicator i, and $v_i(x_i)$ is the rating of an alternative (ecological zone) x with respect to each indicator i. The component utility or value functions $v_i(.)$ and the weights w_i gets values between 0 and 1 and the weights are normalized to sum up to one. The weights w_i tell the relative significance of the change in an indicator i from its lowest level to its highest level, compared to the corresponding changes in the other indicators respectively.

In selecting production sustainability indicators for a particular locality or study, there is the need to consider the following properties: logicality, reliability, scientific justification, and statistical quantification (Erker, et al., 2013). The level of production sustainability was determined on the basis of data for 24 indicators, of which 6 items were used to measure economic sustainability, 11 environmental sustainability aspect and seven (7) social sustainability aspect.

Food security classification

Depending on their mandates and the aims, different individuals and agencies have developed different approaches to assessing food security. However, the theory behind each approach is based on the same underlying concept. This concept incorporates issues of availability and access to food, and acknowledges that, in emergencies, people may adopt varieties of coping strategies in response to food insecurity (UNHCR, WFP & ENN, 2000).

Using responses from the research instrument, a food security index, ranging from 1 to 4 was calculated. The food security index is then used to determine the household's food security category. The food security index indicates whether the household is food secure, marginally food secure, moderately food insecure and severely food insecure. Thus, a four scale was formed from the CARI console to classify the households into the food security levels.

The CARI console's domains represent two key dimensions of food insecurity. The first domain, current status domain, employs food security indicators which measure the adequacy of households' current food consumption. Specifically, this domain is based on the food consumption score and/or food energy shortfall indicators. The second domain, coping capacity domain, employs indicators which measure households' economic vulnerability and asset depletion. Specifically, this domain is based upon a combination of the livelihood coping strategy indicator and either the food expenditure share indicator or the poverty status indicator. A schematic illustration of final food security outcomes for different indicator combinations is presented in Appendix B1.

For the purpose of this study, the food consumption score was used to measures the current status domain. This was done by allocating households into groups based on the variety and frequency of foods consumed. The coping capacity domain was measured using both the livelihood coping strategy and the food expenditure share. The food expenditure share measures economic vulnerability. Households were categorised based on the share of total expenditures directed to food. The livelihood coping strategy measures sustainability of livelihoods. Households were categorised based on severity of livelihood coping strategies employed. This combination of the food security indicators are most commonly used for a study of this nature (WFP, 2015).

A central stage of the console methodology involves converting the outcomes of each console indicator into a standard 4-point classification scale. The 4-point scale assigns a score (1-4) to each category. Within each of the two domains (current status and coping capacity), the 4-point scale indicator scores are then averaged to establish the household-level summary indicators. These summary indicators are then averaged to establish household's overall food security classification. The averaging procedure for adapting the console scores into the overall food security classification.

After converting the food security indicators in the console to a 4-point scale, the overall food security classification for the Maize farming household was then calculated following the steps described below.

1. Calculating the summary indicator of Current Status (CS) by using the 4-point scale of the food consumption score indicators of the households.
2. Calculating the summary indicator of Coping Capacity by averaging the household's console scores (i.e. the 4-point scale scores) of livelihood coping strategy and food expenditure shares in the Coping Capacity domain (CC).
3. Averaging these results in steps 1 and 2 (CS+CC)/2.
4. Round to the nearest whole number to represents the households' overall food security outcome.

The console itself serves to provide a clear snapshot of the rates of the different types of a population's food insecurity at quick glance. An example of completed CARI reporting console is presented in Appendix B2. The final row of the console presents the population's overall food security outcome; this is described as the food security index. This is based on an algorithm which combines, at the household level, the results for each of the reported food security indicators. A household classified as food secure has the ability to meet essential food and non-food needs without engaging in atypical coping strategies. Those classified as marginally food secure have minimally adequate food consumption without engaging in irreversible coping strategies; they are unable to afford some essential non food expenditures. Those classified as moderately food insecure have significant food consumption gaps, or marginally able to meet minimum food needs only with irreversible coping strategies. Households with severely food insecure category have extreme food consumption gaps, or have extreme loss of livelihood assets which will lead to food consumption gaps, or worse (WFP, 2015).

Analytical model for the determinants of food security status

The econometric analysis employed to test for the determinants of household food security was the logistic regression. Several studies employed the binary logit model to estimate the determiants of food security (e.g. Shiferaw, Kilmer, & Gladwin, 2003; Bogale & Shimeles, 2009; Tagel & Van der Veen, 2010; Manu, Akuamoah-Boateng, & Akaba, 2013; Mequanent, Birara, & Tesfalem, 2014; Hailu, Alemu, & Zaid, 2018). Following such studies, the four scale food security levels were collapsed into two by groupping food secure and marginally food secure householfd into food secure category whiles moderately food insecure and severely food insecure were groupped into food insecure category. The study also adapted model specified Gujarati (2004) as follows:

$$P_i = E(|Y = 1| X_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n)}} \qquad (3.8)$$

$$P_i = \frac{1}{1 + e^{-Z_i}} \qquad (3.9)$$

$$Z_i = \beta_0 + \beta_i X_i \qquad (3.10)$$

where, P_i = the probability that a household i will be food secure

Z_i = is the function of the vector of n explanatory variables

If P_i represents the probability that a household will be food secure, 1-P_i is the probability that a household will be food insecure. Thus,

$$1 - P_i = \frac{1}{1 + e^{Z_i}} \qquad (3.11)$$

The odds ratio for an event (such as food security status of a household) is represented as the probability of the event outcome (food secure) divided by one minus probability of event outcome (food insecure). The odds ratio is derived by dividing equation (3.9) by equation (3.11)

$$\frac{P_i}{1-p_i} = e^{Z_i} \qquad (3.12)$$

Equation (3.12) represents the odds ratio which is the ratio of the probability that a household will be food secure to probability that it will be food insecure. Equation (3.12) can be transformed into an alternative form of logistic regression equation by taking the Naperian logarithm of the odds ratio popularly known as logistic transformation (Logit) to obtain equation (3.13) (Gujarati, 2004; Park & Hastie, 2007). The natural logarithm of the odds ratio is is threrefore given as:

$$L_i = \ln(\frac{p_i}{1-P_i}) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n \qquad (3.13)$$

where β_0 is the intercept, $\beta_1 ... \beta_n$ are the coefficients of the predictors in the model and X_1 ... $_n X_n$ are the predicting variables in the model. The logit (L_i) shows the log odds in favour of food security status changes as the respective independent variable changes by a unit (Tagel & Van der Veen, 2010; Manu, Akuamoah-Boateng & Akaba, 2013; Hailu, Alemu, & Zaid, 2018).

Taking the error term into consideration, the logit model becomes

$$L_i = \ln(\frac{p_i}{1-P_i}) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + u_i \qquad (3.14)$$

The intercept and coefficients of the predicting variables can be estimated using the maximum likelihood (ML) method (Gujarati, 2004; Bogale & Shimeles, 2009; Hailu, Alemu, & Zaid, 2018).

Wald test of significance for the model parameter

To determine the significance of the coefficents of explanatory variables, either the Wald statistics or the Likelihood ratio test could be conducted (Healy, 2006; Ogunfiditimi & Oguntade, 2014). The Wald statistic is a method to test whether the coefficients are significantly different from zero. It is used to test the statistical significance of each coefficient (β) in the model. The *Wald statistic* is used to test the linear hypotheses about the regression coefficients, and it is based on large sample sizes, i.e., the large-sample normality of parameter estimates.

A Wald test calculates a Z statistic is given in equation (3.15).

$$z = \frac{\hat{\beta}_i}{se_{\beta_i}} \tag{3.15}$$

This Z value is then squared, yielding a Wald statistics with a chi-square distribution. For instance, to test the null hypothesis that a single parameter estimate equals 0, the *Wald statistic* is given by:

Wald, $\hat{\sum}_{\hat{\beta}}$

The Wald statistic is asymptotically distributed as χ^2 with 1 degree of freedom. The estimated standard error of the ith estimated coefficient, se_{β_i}, is the square root of the ith diagonal element of the estimated covariance matrix $\hat{\sum}_{\hat{\beta}}$, that is, se_{ii} (STATISTICA, 2013).

Likehood ratio test of independence

The likelihood-ratio test uses the ratio of the maximised value of the likelihood function for the full model (L_I) over the maximised value of the likelihood function for the simpler model (L_0) (Ogunfiditimi & Oguntade, 2014). The likelihood-ratio test statistics is given in equation (3.16) as

$$z = \frac{\hat{\beta}_i}{se_{\beta_i}} - 2\log\left(\frac{L_0}{L_1}\right) = -2[\log(L_0) - \log(L_1)] = -2(L_0 - L_1) \qquad (3.16)$$

This log transformation of the likelihood functions yields a chi-square statistic.

Factors Constraining Maize Production in the Volta Region of Ghana

In identifying the most important constraints that are affecting maize production enterprises in the Volta Region, the Garret ranking technique was employed. Apart from the Kendall's ranking of concordance and the Friedman's ranking approaches, the Garrett ranking technique proposed by Garrett and Woolworth (1969) is another method used to rank factors affecting a population. Unlike the other ranking methods which expect respondents to identify and rank all factors, the Garrett ranking techniques' usefulness stems from the fact that respondents only rank identified factors that affect them or they relate to. The Garrett ranking involves presenting a list of factors for respondents to identify and rank. The identified factors are converted to percentage positions using the Garrett formula. The percentage positions are then converted to scores using the Garrett conversion table. This method of identifying the most important factors is described below.

The Garrett ranking technique

This method is proposed by (Garrett & Woolworth, 1969). The technique involves making a list of factors of importance available to respondents to identify and rank. The ranks are then converted to percentage positions using the Garrett formula. The percentage positions are compared to the Garrett score table to read the corresponding scores and for a particular factor, the Garrett scores are added and the mean is found per the number of respondents who ranked that particular factor. The mean scores for all factors are arranged in descending order, thus the factor with the highest score is deemed the most important factor, which is followed by the next higher score till the least score meaning the least important factor (Kumar & Kumar, 2008; Kathiranwan *et al.,* 1999; Sedaghat, 2011) to rank factors affecting respondents. A critical analysis of the Garrett ranking technique is its usefulness in the analysis of factors of a heterogeneous group who may differ due to location, ecology or by climatic conditions. Thus, the Garrett method allows the respondent to first identify which factor(s) affect them, before ranking these factors. The method provide a means of dealing with missing cases, since respondents are not likely not choose factors which are not relevant to them. The Garrett ranking technique has an in-built test of agreement approach, where the mean of scores are found per those who rank the particular factor. Thus, since all respondents have equal opportunity of identifying and ranking some or all the factors, the final mean score reflects the position of the entire sample. Therefore, the Garrett ranking technique is very useful in making policy recommendations for a diverse population. This method is used in this study, since the study covers a wide geographical area in reference to the Western Region of Ghana. The application of the Garrett ranking technique is explained further under method of analysis.

The Scores are then summed and the mean is found per number of respondents who ranked the factor. The final stage of the Garrett ranking technique is the arrangement of mean scores in descending order of importance and inferences are drawn (Kathiranwan et al., 1999; Kumar & Kumar, 2008; Sedaghat, 2011). The Garrett Ranking Technique is very useful in a heterogeneous population or sample regarding the making of generalization as well as making policy decisions. The Garret Ranking

Technique was employed to rank the production and Post-harvest constraints facing the maize farmers in the Volta Region. The Garrett's formula for converting ranks into percent positions is given as:

$$\text{Percent position} = 100 * (R_{ij} - 0.5)/N_j \quad (3.30)$$

where, R_{ij} = rank given for i^{th} constraint by j^{th} individual;

N_j = number of constraint ranked by j^{th} individual.

The percent position of each rank was converted into scores with reference to the Garrett Conversion table by Garrett and Woodworth (1969).

For each of the production and Postharvest constraints, the scores of individual respondents are summed and divided by the total number of the respondents who ranked that particular constraint. These mean scores for all the constraints are arranged in descending order of mean score.

The steps followed in the analysis are illustrated below in following Uppar (2007) as:

Table 3a: Identification and ranking of constraints of Farm Households

Constraints/ Respondents	A	B	C	D	F	G	H	I	J	K	L
1	2	5	1	-	4	3	-	6	7	8	-
2	12	1	11	2	3	4	7	5	8	9	6
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
i^{th}	-	3	1	5	7	-	2	4	-	-	-

Source: Field survey, Akaba (2018).

The identified production and post-harvest constraints obtained from literature were provided to farmers to identify and rank in order of importance, where the most pressing is ranked 1 to the i^{th} constraint being the least pressing constraints of the j^{th} respondent. As shown in Table 3a. The constraints are labelled A-L and figures shows rank assigned to identified constraints. The dash (-) shows a non-identified and ranked constraints.

Table 3b: Conversion of ranked constraints into percentage positions using the Garrett formula

Constraints/ Respondents	A	B	C	D	E	F	G	H	I	J	K	L
1	b	e	a	-	-	c	-	f	G	h	-	d
2	l	a	k	b	c	d	g	e	H	i	-	f
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
i^{th}	-	c	a	e	g	-	b	d	-	-	-	

Source: Field survey, Akaba (2018).

After the identification of the constraints, each rank given by particular respondents are converted to percentage positions using the Garrett formula with per the total number of constraint ranked by the said respondents. As shown in Table 3b, the converted ranks to percentage positions are illustrated by small alphabets a-b. Dash (-) show non converted ranks due to non-identification and ranking by the respondent.

Table 3c illustrates the conversion of percentage positions into scores using the Garrett conversion table, as shown in Appendix C. The Scores are denoted by XX. The subscripts denote the magnitude of the scores for particular respondents. That's X_1 is bigger than X_2 in that order.

Table 3d shows the sum of scores in column (5) denoted by XX and Mean of Scores denoted by Y in Column in (6).

Table 3e shows ranks in column (4) given to the mean scores in column 3. The arranged ranks are shown in column 5. This depicts the fact the Factor/constraint G is most pressing factor followed by B which is the second constraint till the least ranked constraint being constraint C.

Table 3c: Converted percentage positions into Scores using the Garrett conversion table

Constraints/ Respondents	A	B	C	D	E	F	G	H	I	J	K	L
1	X_2	X_5	X_1	-		X_3	-	X_6	X_7	X_8	-	X_4
2	X_{10}	X_1	X_{11}	X_2	X_3	X_4	X_7	X_5	X_8	X_9		X_6
.	.	.	.	.			.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
ith	-	X_3	X_1	X_5	X_6	-	X_2	X_4	-	-	-	

Source: Field survey, Akaba (2018).

Table 3d: Sum and mean Score Conversion of summed scores to mean scores and Rank

Constraints/ Respondents	A	B	C	D	E	F	G	H	I	J	K	L
1	X_2	X_5	X_1	-		X_3	-	X_6	X_7	X_8	-	X_4
2	X_{10}	X_1	X_{11}	X_2	X_3	X_4	X_7	X_5	X_8	X_9		X_6
i^{th}	-	X_3	X_1	X_5	X_6	-	X_2	X_4	-	-	-	
Sum of Scores $\sum X$	XX_1	XX_2	XX_3	XX_4	XX_5	XX_6	XX_7	XX_8	XX_9	XX_{10}	XX_{11}	XX_{12}
Mean Scores $\sum X / N$	Y_1	Y_4	Y_5	Y_6	Y_2	Y_3	Y_7	Y_{10}	Y_9	Y_{11}	Y_{12}	Y_8

Source: Field survey, Akaba (2018).

Table 3e: Ranked constraints of respondents

Constraints	A	B	C	D	E	F	G	H	I	J	K	L
Sum of Scores ($\sum X$)	XX_1	XX_2	XX_3	XX_4	XX_5	XX_6	XX_7	XX_8	XX_9	XX_{10}	XX_{11}	XX_{12}
Mean Scores ($\sum X / N$)	Y_1	Y_4	Y_5	Y_6	Y_2	Y_3	Y_7	Y_{10}	Y_9	Y_{11}	Y_{12}	Y_8
Rank	4	2	11	10	3	9	8	1	7	6	12	5
Rank Arranged	H	B	E	A	L	J	I	G	F	D	C	K

Source: Field survey, Akaba (2018).

The respondents were asked to rank the twelve production constraints identified for the purpose of this study as 1, 2, 3, 4, ..., 12 in order to know their preference in the selection of constraints. The calculated percentage position for the rank 1, 2, 3, ..., 12 and their correspondent Garrett table as show in Table 3e for factors, the total score is calculated by multiplying the number of respondents ranking such factor as 1, 2, 3, ..., and 12.

Ethical Considerations

The study required interacting with farmers who have different forms of experiences from farming, food security and climate change effects. Exposure to the extreme form of any of these could hurt in diverse ways. Interaction with the respondents for data collection was in their homes or farms, and the meeting was done anywhere convenient for the respondents, with some considerable space to prevent distractions from other events in the environment. This could interfere with the privacy of some participants who did not have very decent environment; a situation that could be embarrassing and possibly caused psychological harm.

As an initial step in the ethical procedure, all the participants offered voluntary informed consent to participate in the study. Maize farmers who were identified as subjects in the selected areas for the study were given thorough explanation about the research including its objectives. Through this, they were informed about the nature of the study and what the entire farmer population stands to benefit in future and subsequently had the chance to ask questions for clarification. This briefing convinced most of the farmers from the initial stages of the research to give verbal consent for the research. Assurance was given to the consenting maize farmers that their anonymity would be our concern; and all information would be handled at highly confidential level. Participants were encouraged to withdraw from the interview if they felt uncomfortable to continue with their participation in the study even after giving their approval. Some few farmers refused outright with their main reason that they were involved in similar interactions earlier with no material rewards.

Limitations of the Study

The cross-sectional nature of the study does not permit speculation about the causal direction of the relationships observed between food security and perceptions on climate change, attitudes towards sustainable agriculture, practises of sustainable agriculture or other correlates. Determining whether food security among the sample studied is a transient or stable phenomenon is not possible. Although the data from this study are self-reported, the survey was anonymous and the researcher has no reason to believe that any under- or over-reporting occurred. There is the possibility of selection bias caused by missing farmers who travelled out of their community for economic, social or other reasons.

Before aggregating the sustainability indicators into parameters, the decision about the importance of individual indicators for achieving the overall sustainability, namely the weights assigned to individual indicators, should have been reached. Due to the inability to acquire the appropriate analytical tools for the study, the indicators could not be weighed but given equal weight of 1 if it contributes to sustainability and 0 if otherwise. Furthermore, since the most important part of this study is not assessing the importance of the parameters, but rather their presence or practises, the inability of weighing individual indicators may not have too much influence on the outcome of the study. However, the weights of individual sustainability components (economic, environmental and social) were assigned the ratios of 0.3:0.3:0.4, according to the standards in literature (Vecchione, 2010; Erker et al., 2013).

Some of the respondents were not able to complete all the items on the research instrument. Few others walked out from participating in the study. The most common reasons for the non-participation and inability to complete the research instrument were the time commitment and lack of interest.

Summary

This chapter presented and discussed the philosophical and methodological choices used for the study as well as justification for the chosen approaches and variables. The pragmatist philosophy underlying the study was discussed with its strength and limitations highlighted. The chapter also provided justifications for the choice measurement indicators as well as estimated models for empirical analysis. The framework for data analysis was also provided by specifying the key research objectives with their corresponding dependent and independent variables and the kind of analysis that was performed in achieving the specified objectives. Ethical considerations in the study was also presented in this chapter.

CHAPTER FOUR

STATE OF MAIZE PRODUCTION SUSTAINABILITY IN THE VOLTA REGION

Introduction

Maize is the most widely grown and consumed staple crop in the Volta Region. It is both used as staple and industrial crop in Ghana and for feeding livestock. Maize farming in the region is mostly by smallholder farmers under rain-fed conditions across the various agro-ecological zones. This chapter presents the empirical findings of the analysis on the state of maize production sustainability in the Volta Region. The chapter consists of four sections; namely description of the farm- and farmer-specific characteristics of the Maize farming households, livelihood diversifications of these households and the constraints facing the maize production enterprise among the households. The chapter also presents a comparative analysis of most of the findings based on the geographical zones in the region. It also delves into the sustainability of maize production systems in the study area. It specifically evaluates farmers' attitudes towards sustainable production and socio-economic backgrounds that influence their attitudes. It finally examines sustainable production practices by these farmers and their associated determinants.

Farm- and Farmer-Specific Characteristics of Maize-Farming Households

Maize farming in the region is predominantly male dominated farming activity (Table 4). For instance, in the North and Middle zones, approximately 4 out of every 5 respondents were males while less than a third of the respondents in the South zone were females. In all, less than a quarter of the farmers were women. The inequality that exists in accessing and owning resources between males and females greatly determines the level of involvement of the various members in the households in various farming activities. As suggested by FAO (2011) strengthening women's access to and control over resources is an important means of raising their status and influence within households and communities. Improving women's access to land and security of tenure has direct impacts on farm productivity, but can have far reaching implications for improving household welfare as well. Women who engaged in agriculture face gender-specific constraints that limit their access to productive inputs, assets, and services.

Table 4: Percentage distribution of sex respondents within the three geographical zones

Sex	Geographical zones			Pooled
	North	Middle	South	
Female	21.2	20.1	31.1	24.1
Male	78.8	79.9	68.9	75.9
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018).

Enete et al. (2011), and Enete and Onyekuru (2011) found that age is a factor driving farmer's investment in climate adaptation practices. While over 40 percent of the farmers from the Northern Volta were less than 40 years, only less than a quarter of those from the Middle and Southern zone were within this age groupings (Table 5). However, majority of the farmers were within the age groupings of 40 to 59 years across the various geographic locations in the region. From the Northern zone, about a quarter each of the respondents were within the age groups of 40-49 and 50-59 (25.9% and 24.1% respectively. The Middle zone showed more than a third of the farmers (33.9%) in the age of 40-49 years while a little more than a quarter (25.5%) were in the 50-59 age groups. For the Southern zone, while more than a third (34.8%) were in the 40-49 years category, less than a third of them (31.6%) were in the 50-59 years group. Only few respondents (9.2%, 17.6% and 10.2% from the Northern, Middle and Southern zones respectively) were at least 60 years old.

Table 5: Percentage age distribution of respondents by zones

Age of respondents	Geographical zones			Pooled
	Northern	Middle	Southern	
20-29	11.4	7.5	6.6	8.4
30-39	29.4	15.5	16.8	20.4
40-49	25.9	33.9	34.8	31.6
50-59	24.1	25.5	31.6	27.1
60-69	7.9	13.4	4.9	8.7
70-79	0.9	3.8	4.5	3.1
>80	0.4	0.4	0.8	0.6
Total	100.0	100.0	100.0	100.0
	ANOVA mean separation			
Mean	43.65^{a}	47.96^{b}	47.68^{b}	46.13
St. Dev.	11.78	12.05	11.60	11.95
Minimum	20	20	20	20
Maximum	86	86	82	86

Source: Field survey, Akaba (2018).

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

The ages of the respondents ranged from as low as 20 years to as high as 82 or 86 years depending on the Geographical zones the respondents are coming from in the region. The mean age values show indication of having a youthful maize farmers in the region, though this should be said with some level of caution since the corresponding standard deviations are very wide (Std.Dev. ranging from 11.6 to 12.05). An ANOVA conducted indicated that the respondents from the Northern zone were significantly younger than those from Southern and Middle zones.

Menker (2016) however indicated that farmers all over the world are getting older. He reported the risk of not having the required human capital in the farm sector in the near future. In Ghana, majority of the population are below 24 years. Having mean above 45 years calls for concern about eminent inadequacy of enough farmers to feed the country in the next generation. The wide disparity in the average ages could be of the fact that young people face myriads of bottlenecks such as access to land and other capital resources when they venture into farming. As posited by Menker (2016), in a situation where most farm lands are already occupied, young people tend to shift their focus to more attractive opportunities in other sectors.

Table 6: Percentage distribution of marital status of respondents by zones

Marital status	Geographical zones			Pooled
	Northern zone	Middle zone	Southern zone	
Single	11.9	8.3	4.2	8.2
Divorced/Separated	7.8	4.6	7.9	6.8
Widowed	1.2	4.1	6.3	3.9
Co-habitation	1.2	0.4	2.5	1.4
Married	77.8	82.6	79.1	79.8
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018).

Most of the respondent maize farmers were married across the three geographical areas (Table 6). Approximately about 4 out every 5 maize farmers are married. Among those who are single or never married in their life, a greater proportion are from the Northern zone; in addition, divorced or separated cases are high in the North and South of Volta than in the Middle zone. Only a few of the respondents are into co-habituation or consensual relationship.

Table 7: Percentage distribution of level of education of respondents by zones

Highest level of education	Geographical zones			Pooled
	Northern	Middle	Southern	
No formal	25.3	4.7	13.8	14.9
Primary	10.1	12.3	21.7	14.8
Adult literacy	1.7	0.0	0.4	0.7
JHS/MSL	34.6	57.5	42.9	44.6
SHS/'O' Level	20.7	15.6	17.5	18.0
Diploma/Cert A (Agric/Teacher)	4.6	7.5	2.5	4.8
University	3.0	2.4	1.3	2.2
Total	100.0	100.0	100.0	100.0
ANOVA mean separation				
Mean years of education	7.89^{a}	10.37^{b}	8.41^{a}	8.87
Std.Dev.	5.44	3.35	4.13	4.60
Minimum	0	0	0	0
Maximum	24	22	24	24

Source: Field survey, Akaba (2018).

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

The results in Table 7 reveal that as high as a quarter of the farming respondents from the Northern part of the region had no formal education while less than 5 percent and about 14 percent of the respondents from the Middle and Southern parts were also in that category. In fact, about 63 percent of the farmers in the Northern zone had at least completed basic education. For those farmers from the Middle part of the region, at least 8 out of every 10 of them had completed basic or higher education. On the other hand, about two-thirds of the maize farmers from the south of Volta had at least basic education.

Table 8: Percentage distribution of household size by zones

Household Size	Geographical zones			Pooled
	Northern	Middle	Southern	
1-3	11.2	12.4	16.7	13.4
4-6	33.6	51.3	44.0	42.8
7-9	28.2	23.9	30.8	27.7
10-12	14.5	8.0	4.3	9.0
13-15	8.3	2.7	1.7	4.3
16-18	2.5	0.9	1.3	1.6
>19	1.7	0.9	1.3	1.3
Total	100.0	100.0	100.0	100.0
ANOVA means separation				
Minimum	1	1	1	1
Maximum	27	25	32	32
Mean	7.66^{b}	6.34^{a}	6.30^{a}	6.78
St. deviation	3.97	3.22	3.79	3.74

Source: Field survey, Akaba (2018).

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

With this revelation, it could be realized that those who had attained tertiary education were minimal (7.6%, 9.9% and 3.8% respectively for Northern, Middle and Southern zone). An ANOVA conducted on the mean number of years of education among the farmers indicated that, those farmers from the north and south part of the region had significantly lower level of education than their counterparts from the Middle zone.

It is argued that individuals who have some level of education tend to understand and better apply technologies and skills introduced to them more than less educated ones (Ibrahim et al., 2009). As reported by Sadati et al. (2010), literacy influence attitudes towards best practices that can lead to sustainability in the agricultural production system.

While majority of respondents from Middle zone had household sizes ranging from 4 to 6 members, a third and at least 2 out of 5 respondent households in the Northern and Southern zones respectively had the same range of household size (Table 8). In the Northern zone, 27 percent of the respondents had more than 9 member households, 12.5 percent of respondents from Middle zone had household sizes more than 9 while less than 10 percent (8.6%) of respondents from the Southern zone had household sizes more than 9 members. Thus those respondents from the Northern zone tend to have larger household sizes than those from the middle and southern zone. The ANOVA indicated that the Northern zone households have significantly larger household sizes (Mean ≈ 8.0) than their counterpart households in the Middle and Southern zone (Mean ≈ 6.0 each).

Larger household size is expected to increase production, especially where there are more adults working force in the household, due to the fact that there could be more family labour for the Maize farming households. This is supported by Weiss and Briglauer (2000) and Benin et al. (2004). As posited by Reardon (1997), family size affects the ability of a household to supply labour to the farm. In a large family some members could remain engaged in agricultural production activities.

Table 9: Percentage distribution of respondents according to number of years of growing maize by zones

Years	Geographical zones			Pooled
	Northern	Middle	Southern	
< 5	37.0	18.5	9.5	21.6
5 - 9	18.7	15.9	9.5	14.7
10 - 14	15.7	15.9	20.3	17.3
15 - 19	7.4	8.4	12.1	9.3
20 - 24	7.4	18.5	17.7	14.5
25 - 29	2.6	8.4	9.1	6.7
30 - 34	7.0	6.6	15.9	9.9
> 34	4.2	7.8	5.9	6.0
Total	100.0	100.0	100.0	100.0
	ANOVA mean separation			
Minimum	1	2	1	1
Maximum	50	60	60	60
Mean	11.32[a]	16.14[b]	18.83[c]	15.45
St. deviation	10.06	11.69	11.21	11.42

Source: Field survey, Akaba (2018).

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

More than 1 out of every 5 farmers interviewed started producing maize less than 5 years ago. However, in the Northern Volta, more than a third had less than 5 years of experience in maize farming. This could be due to the fact that respondent farmers from the north of Volta have relatively younger members than other parts of the region (Table 9), especially those between the ages of 20 to 39 years. Again, about a third each from the various geographical zones was producing maize for the past 5 to 14 years. This is an indication of having more than half of the respondents producing maize for less than 15 years. Nevertheless, more than 46 percent had from 15 to 60 years of experience in maize farming. The overall mean of all the respondents was above 15 years though those from the North had only about 11.3 years on the average. This scenario present the fact that the maize farmers generally had substantial experience that could enable them to cope with current climatic extremes and strategize to improve food security status through sustainable production practices. As indicated by Bradshaw et al. (2004) and Egyir et al. (2015), improving adaptive capacity to climate change and variability will help reduce vulnerability and able to cope with the consequences thereof. An ANOVA conducted indicated that there were significant differences in the years of Maize farming among the farmers from the three Geographical zones in the Volta Region. Thus the Southern zone farmers had significantly more experience in Maize farming than those from the Middle zone which were also more experience than their counterparts in the Northern zone.

The results in Table 10 reveal that more than 7 out of every 10 maize farmers in the Northern zone was using monocropping, majority of those from the Middle zone and less than 20 percent of those from the South were using the monocropping system. On the other hand, majority of the respondents from the south were more involved in mixed cropping system, more than a quarter of those from Middle zone and less than 2 out of every 10 maize farmers from the North were involved in the mixed cropping system. While less than 5 percent of those farmers from the south and north were involved in seasonal cropping, more than 15 percent of those from Middle zone were practising seasonal cropping. Those farmers who are into seasonal cropping always wait for the maize cropping season to do their farm. They mostly have other livelihood activities as their main source of income. Their involvement in the maize production is purposely for consumption, hence the wait for the major season to enter into maize production. Other few farmers also practised strip cropping, and continuous cropping. However, these practices are location specific.

Table 10: Maize production systems in the Volta Region

Production system	Geographical zones			Pooled
	Northern	Middle	Southern	
Monocropping	73.2	53.6	19.8	48.9
Mixed cropping	19.7	26.0	63.7	36.4
Shifting cultivation	1.3	2.1	8.9	4.1
Seasonal cropping	3.8	15.7	3.4	7.6
Continuous cropping	2.1	0.0	1.7	1.3
Relay/Strip cropping	0.0	2.6	2.5	1.7
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018).

The kind of cropping systems adopted by maize farmers in the study area could be influenced mainly by the land tenure system. As revealed by the results in Table 10, those farmers from the Northern Volta who have large areas of arable land for farming tend to practise monocropping, unlike their counterparts from the Southern Volta. The unavailability of enough and secure lands in the south has been driving farmers to produce many crops on the small parcels of land that they are able to acquire. These lands in the south typically have alternative uses which the owners think will bring higher returns to their households more than using them for farming activities. The land tenure system in the south is characterised by small land sizes and pressure from competing and alternative uses, most especially from the infrastructural developers. Those proportions with shifting cultivation in the south were as a result of the pressure on land where most of the places that are being used for Maize farming are used for construction purposes hence the need to move to other areas for their maize production activities. Sometimes, the farmers combined one or more farming systems. This suggests that the farmers diversify their production because of the risks and uncertainties involved in farming activities (Adegeye & Dittoh, 1985).

Table 11: Purpose for growing maize

Purpose	Frequencies	Percent
Source of food	702	95.8
Source of income	664	90.6
Easy to work in maize farms	82	11.2
Main source of employment	49	6.7
Early maturity and high yielding potential	35	4.8
High market demand for maize products	17	2.3
Major crop for the area	13	1.8

Source: Field survey, Akaba (2018) Multiple responses, n = 733

The two most important reasons why farmers go into maize production in the study area were that Maize farming serves as sources of food security and income (Table

11). Other reasons given by the respondents, though minimal but very relevant, include easy to work with, serving as main source of employment, early maturing and high yielding potential of the maize plant, its ability to have high market demand, and serving as a major crop grown in the area. Thus, Maize farming business is seen to be relatively easier working compared to other farming businesses like vegetables and rice farming. Maize is also seen as a crop that is early maturing and having high yielding potentials, which brings about quick returns within 2 to 3 months unlike other crops such as cassava and yam. Others also see it as an easy source of employment for their livelihoods.

Main Occupation of Respondents

The main occupations of respondents are presented in Table 12 and it shows that most (90%) of the respondents in the Northern zone have farming as their main occupation and the remaining 10 percent are involved in off-farm (processing) and non-farm (artisanal work) occupations. Again, about three-quarters of the respondent from the Middle zone and about 61 percent of those in the Southern zone are involved in farming as their main occupation. It is not surprising that most of the respondents are into farming because Adi (2013) indicated that, in most cases, a household has one distinct occupation, which it considers primary and to which more labour and time are allocated relative to other activity or activities.

Highlights of the occupational analysis by Abimbola and Oluwakemi (2013) revealed that more than half of the rural households were engaged in farming as their primary occupation, indicating that farming is the predominant occupation in the study area, and this is similar to the result found in this study. It is expected that most households in the rural areas would depend mainly on agriculture as their primary source of livelihood. African farmers diversify their livelihood strategies through on-farm and off-farm activities (Ellis, 1998, 2000).

Table 12: Respondents' main occupation by zones

Occupations	Geographical zones		
	Northern	Middle	Southern
Farming	90.2	75.4	61.3
Off-Farm	4.1	3.7	4.5
Non-farm	5.7	20.9	34.2
Total	100	100	100

Source: Field survey, Akaba (2018)

Livelihood Diversification of Maize-farming Households in the Volta Region

Table 13 shows the livelihood diversification of respondents in the Volta Region of Ghana. It was clear that all the respondents in the three Geographical zones were all involved in farm activities. However, on the off-farm activities, about three out of ten respondents were from the Northern zone, one out of ten were from the Middle zone and Southern zone. This indicates that more farming households in the Northern zone were involved in off-farm activities than their counterparts in the middle and southern zones. On the non-farm activities, majority of the respondents were from the Southern zone whiles about half of the respondents are from the Middle zone and a little over a quarter of the respondents were from the Northern zone. This may be as result of the fact that there are no arable lands in the southern part of Volta and so people living there are most engaged in non-farm activities such as fishing, fish processing, and petty trading, among other activities.

There is evidence that non-farm activities in both the rural and urban areas are widespread in Ghana. For instance the Ghana Statistical Service (2007) estimates that 46.4 percent of households in Ghana operate non-farm enterprises. A case study of four rural communities in three ecological zones of Ghana by Oduro and Osei-Akoto (2007) also gave further credence to this observation. Also, according to the study, residents in these villages were found to be employed in a number of non-farm activities, such as hairdressing, carpentry, tailoring, trading, "pito" brewing, food processing, charcoal trading, masonry, non-traditional animal husbandry (Rabbit and Grasscutter rearing), sewing, teaching, and nursing. Aduse-Poku et al. (2003) also laid emphasis on the fact that, rural livelihood options found in Ghana include farming (crop production and animal rearing), gathering, hunting, trading, craft making, and public or civil service. In their study, Abimbola and Oluwakemi (2013) found that almost three-quarters of their households engaged in a combination of farm and non-farm activities.

Table 13: Types of household livelihood diversification by geographical zones

Livelihood diversification	Geographical zones		
	Northern	Middle	Southern
Farm Activities	100	100	100
Off-Farm Activities	27.2	10.2	13.6
Non-farm Activities	31.3	52.5	64.2

Source: Field survey, Akaba (2018)

The purpose for farm households to diversify is to gain higher incomes and also to ensure food security. Agbola et al., (2008) found wealthier farm households to be food secured compared to their poor counterparts who were food insecure and less diversified. Other literatures alluded to the fact that diversification increase income levels of households (Reta & Ali, 2012; Gebreyesus, 2016). Farmers use income from livelihood diversification to purchase inputs such as fertilizer and improved seeds to increase productivity of their farm holdings. These incomes from alternative livelihoods tend to relieve the farmers from credit constraints to intensify agricultural production (Apata, 2009).

Number of maize varieties produced by respondents

A cross-tabulation of the number of varieties produced by respondents and the three Geographical zones is shown in Table 14. Different maize varieties were under cultivation by the respondents as shown in Table 15. Table 14 shows that most farmers in the study area planted a combination (in twos, threes, or fours) of these varieties and this can be influenced by several factors including price, yield, pest, disease or drought resistant. The results show that more than 70 percent of the respondents grow at least two maize varieties. This indicates that majority of the farmers diversify their maize production by growing more than one variety.

Within the Geographical zones, close to a third each in both the Northern and Southern zones planted one variety while only about a quarter in the Middle zone produced one variety. Majority of the farmers planted 2 or 3 varieties. These are mostly done to avert crop failure due to disease outbreak and climate change effects. Thus, among the farmers, it is believed that some of the varieties could withstand extreme climatic conditions, others could withstand outbreak of diseases and pests while others could be high yielding or appealing to the demands in the market. The production of these varieties that have different purposes helps increase the farmers' resilience and ability to adapt to shocks and negative impact of external factors such as diseases, pests and climate extremes.

Table 14: Number of maize varieties planted by geographical zones

Number of varieties	Geographical zones			Pooled
	Northern	Middle	Southern	
1.00	32.2	24.6	30.7	29.2
2.00	44.5	43.4	52.0	46.7
3.00	22.4	30.7	16.0	23.1
4.00	0.8	1.2	1.2	1.1
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018)

Types of maize varieties produced by respondents

The result as shown in Table 15 reveals that there are as many as 21 different maize varieties cultivated in the Volta Region of Ghana. Among these maize varieties produced, *Obaatampa* variety is the most cultivated maize variety given that almost two-thirds of the respondent in the three geographical zones were into the cultivation of *Obaatampa*. Again, it is evident from Table 15 that the top five most cultivated maize varieties in the study areas were *Obaatampa*, *Local*, *Dzinueve*, *Proceed* and *Mamaba*. Wheras the the least cultivated varieties were *Aburohemaa*, *Abontem*, *Omanka, Enibi* and *Afetor*. It could also be due to the fact that the region is made up of different agro-ecological zones hence the diversity in the number of varieties grown in order to stay in business irrespective of one's location.

Table 15: Percentage distribution of maize varieties produced in the various geographical zones

No	Varieties	Geographical zones			Pooled
		Northern	Middle	Southern	
1	Obaatampa	69.5	57.0	65.4	64.0
2	Local	11.8	31.1	12.8	18.6
3	Dzinueve	4.9	7.8	20.2	10.9
4	Proceed	6.9	28.2	-	10.0
5	Mamaba	11.4	2.0	3.7	5.7
6	Pana	6.1	-	4.9	3.7
7	Dorke	3.7	3.7	3.3	3.5
8	Etubi	0.4	0.4	9.1	3.3
9	Duati	-	0.4	9.1	3.1
10	Abelehee	4.5	1.6	1.6	2.6
11	Pioneer	7.3	-	0.4	2.6
12	Domabin	6.9	-	-	2.3
13	Atile	0.4	1.6	4.5	2.2
14	Akporsoe	0.4	3.3	0.8	1.5
15	Dobidi	2.8	0.8	-	1.2
16	Laposta	1.6	0.4	0.8	1.0
17	Afetor	-	0.8	1.6	0.8
18	Enibi	-	-	1.2	0.4
19	Omanka	-	1.2	-	0.4
20	Abontem	0.4	-	0.4	0.3
21	Aburohemaa	0.4	-	0.4	0.3

Source: Field survey, Akaba (2018)

For instance, apart from *Obaatampa* which is generally produced throughout the region, *Proceeds* and *Local* were mostly produced by farmers in Middle zone while *Dzinueve, Etubi* and *Duati* were mostly produced by farmers from the Southern zone. *Mamaba, Pioneer, Pana,* and *Dormabin* were mostly found in the Northern zone. As indicated by Iiyama et al. (2008), inputs availability, consumer demands, environmental attributes, and soil management techniques in a particular location could influence the cropping system and the type of diversification to adopt.

Number of crops grown by respondents

The number of crops grown by the maize farmers is presented in Table 16. The result shows that in addition to maize, the respondents grow up to 7 different types of crops. At least 1 in every 5 farmers planted at least 2 different crops in addition to maize, and about a quarter of the respondents cultivated at least one crop in addition to maize. However, only few farmers grow more than 5 different crops. The results also reveal that majority of the farmers from the various geographical zones cultivated either 3 or 4 other crops in addition to maize (Northern zone = 66.1, Middle zone = 66.0 and Southern zone = 67.7).

Table 16: Number of crops grown by geographical zones

Number of Crop	Geographical zones			Pooled
	Northern	Middle	Southern	
1	0.8	-	-	0.3
2	21.6	21.7	19.7	21.0
3	38.8	30.3	35.7	34.9
4	27.3	35.7	32.0	31.7
5	7.3	11.5	11.9	10.2
6	3.7	-	0.8	1.5
7	0.4	0.8	-	0.4
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018)

The result on crop diversification, as indicated in Table 17, shows that the respondents were growing about 16 different types of crops made up of arable crops, cash crops and vegetable crops. The result also shows that majority of the farmers are into the production of root and tubers, followed by leguminous crops and vegetables and then other cereals apart from maize. As reported by Saraswati et al. (2011) and Ojo et al. (2014), crop diversification increases food crop output. This has a positive implication for food and livelihood security.

Table 17: Respondents' crop diversification

Crops	Geographical zones			Pooled
	Northern	Middle	Southern	
Cassava	39.3	14.6	12.3	19.3
Banana/Plantain	2.4	16.3	2.8	8.4
Legumes	39.1	11.9	34.3	22.3
Cocoa	3.2	19.3	0	3.9
Coffee	0	0.8	0	0.3
Cashew	0.8	0	0	0.2
Vegetables	18.5	14.2	38.4	21.3
Yam	72.3	33.6	5	37.3
Tobacco	0	1.2	0	0.4
Agushie	0.4	0	0	0.1
Rice	14.2	19.3	2.8	11.9
Potatoes	0.4	0	14.8	4.9
Sugar Cane	0	0.4	0	0.1
Fruits	1.2	3.2	0	1.4
Oil palm	0	5.7	1.2	2.3
Millet	2.8	0	0	0.9

Source: Field survey, Akaba (2018)

Farmers can also diversify in response to biological, physical, or economic constraints that affect the farming system or input availability. These types of constraints can take the form of limited availability of inputs, limited water or nutrient availability, public and private payments for ecosystem services and consumer demand for quality-differentiated products or products with environmental attributes (such as organic or pesticide-free varieties) among others. The result also has implication for soil management as different livelihood diversification strategies correspond to the use of different soil management techniques, as different crop and animal activities (subsistence or commercial) can be managed with differing degrees of intensification (i.e. input usage), and we are not sure whether engagement in off-farm activities will promote or constrain investment in improvements in soil management (Iiyama, Kariuki, Kristjanson, Kaitibie, & Maitima, 2008).

Number of activities for household income

Table 18 presents the number of income generating activities maize-farming households are engaged in and the result shows that the maize-farming households are engaged in up to three different income generating activities (farm, off-farm and non-farm). However, majority of these households were mostly involved in the combinations of two of these income generating activities. Thus, in addition to main farming activities as source of livelihood, households could add either off-farm activity or non-farm activity. Only 11.5 percent of the responding households were involved in all three livelihood activities for their household income and none of them had more than three income generating activities. Table 18 further reveals that, majority of the maize-farming households in the Northern zone (53.9%) were engaged in combination of two activities. About three-quarters (73.4%) from the Middle zone and 7 in every 10 maize-farming households in the Southern zone were respectively involved in a combination of either off-farm or non-farm livelihood activities for household income in addition to their on-farming activities. This indicates that maize farmers were not only depending on farming activities but have diversified their source of income to sustain their livelihoods. This finding supports the assertions by Aduse-Poku et al. (2003), Ghana Statistical Service (2007), and Oduro and Osei-Akoto (2007) that most households in Ghana, especially farmers and those living in the rural communities, are engaged in other income generation activities in addition to their main occupations.

Table 18: Number of household income generation activities by zones

Number of activities	Geographical zones			Pooled
	Northern	Middle	Southern	
1	33.5	17.2	16.0	22.2
2	53.9	73.4	71.7	66.3
3	12.7	9.4	12.3	11.5
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018)

It is evident in a work by Edna, Matthew and Adesope (2007) that rural household in Nigeria engage in multiple livelihood activities such as trading (marketing or adding value to commodities, small scale business enterprises, carpentry, radio and bicycle repairs) and processing of agricultural goods and arts and craft (weaving, mats and basket making) in order to supplement earning from agriculture. However, literature has also shown that diverse income portfolio, creates more income and distributes income more evenly. For example, Ellis (2000) indicated that it is easier to adopt the combined livelihood strategies than switching full time between either of them. In the case of Ghana, there is evidence of households diversifying their livelihoods by considering more local non-farm employment and migration (Lay & Schuler, 2008).

Differences in the levels of livelihood diversifications

One-way ANOVA was used to determine whether statistically significant differences existed among the households' mean level of diversification in terms of number of maize varieties, planted number of other crops grown in addition to maize, and number of income generating activities households were engaged in Table 19 presents these results. The results disclose that the respondents' level of diversification differed significantly within the three geographical zones (Middle, Northern and Southern zones) when it comes to varietal diversification as the $F(2, 730) = 5.353$, and $p = .005$. Moreover, there was statistically significant differences among their level of income diversification since the $F(2, 730) = 6.089$ and $p = .002$.

Table 19: Geographical differences in mean levels of diversifications

Variables		Sum of Squares	df	Mean Square	F	Sig.
Number of varieties produced	Between Groups	5.981	2	2.991	5.353	.005
	Within Groups	407.871	730	.559		
	Total	413.853	732			
Number of crops grown	Between Groups	1.055	2	.527	.519	.595
	Within Groups	741.226	730	1.015		
	Total	742.281	732			
Number of activities for household income	Between Groups	3.913	2	1.957	6.089	.002
	Within Groups	234.572	730	.321		
	Total	238.486	732			

Source: Field survey, Akaba (2018)

However, the level of diversification was not statistically significantly among the geographical zones in terms of number of crops grown since the F(2, 730) = 0.519, and p = .595. This means that though they are in the same region there are differences in terms of the number of maize varieties produced and the number of income generating activities the farming households are engaged in. This could be as a result of many factors including differences in agro-ecologies and market demands for such crops in the region. This indicates that the extent of livelihood diversification depends on the location individuals or households find themselves. Therefore, farmers from different geographical spread like the Volta Region should not be treated as one but rather location specific programmes should be implemented to be able to make higher impact.

The study therefore rejects the null hypothesis that states that there are no significance differences between the three geographical zones when it comes to livelihood diversification. Abimbola and Oluwakemi (2013) opined that combination of factors such as availability of non-farm opportunities, limitation of income from agricultural activities, demand for services, and family size are some for the reasons why households are able to enter into different income generation activities.

Table 20 presents the post hoc analysis of the mean differences in livelihood diversifications of maize farmers. With regards to varietal diversification, using the means, with respect to the various geographical zones, it can be deduced that those from the Middle zone are more diversified than the other two geographical zones, and those in Northern zone are also more diversified than those in the Southern zone. However, the post-hoc test shows that the difference between Southern and Northern zone are not statistically significant but there is a statistical significant difference between the Middle zone and the rest of the geographical zones. This could be due to the kind of agroclimatological conditions that pertain in the Middle zone, where all of the administrative assemblies found within this area can produce maize in both major and minor seasons unlike the Northern zone which is characterized by guinea savannah and Southern zone which is characterized by coastal savanna where they mostly produce maize in one season.

Table 20: Mean differences in livelihood diversifications of maize farmers

Geographical Location	Mean	Std. Dev.	Standard Error Mean
Varietal Diversification			
Northern zone	1.918[b]	0.758	0.048
Middle zone	2.086[a]	0.773	0.049
Southern zone	1.877[b]	0.709	0.045
Pooled	1.960	0.752	0.027
Crop Diversification			
Northern zone	3.314[a]	1.057	0.068
Middle zone	3.402[a]	1.003	0.064
Southern zone	3.385[a]	0.061	0.960
Pooled	3.367	1.007	0.037
Income Diversification			
Northern zone	1.792[b]	0.648	0.041
Middle zone	1.922[a]	0.511	0.033
Southern zone	1.963[a]	0.532	0.034
Pooled	1.892	0.571	0.021

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

As a strategy, some farmers produce particular varieties in the major season and change varieties in the minor season. This has implication for biological pest and disease control and resistance to extreme climate conditions. It could also be that the Middle zone hosts the administrative capital of the region where most of the innovative technologies like improved seeds pass through before disseminating to other parts of the region. Hence those closer to the regional headquarters of most of the agencies and organisations tend to get access to most of these technologies more than those in the hinterlands.

Similar to varietal diversification, crop diversification shows that farmers from Middle zone were more diversified than those from the Southern zone, who were also more diversified than those from the Northern zone. However, the post hoc analysis on the extent of diversification among these three Geographical zones shows no statistically significant difference from each other. The findings pertaining to income diversification indicates that maize farmers in the Southern zone are more diversified in terms of number of income generating activities for household livelihoods than the maize farmers in the Middle zone who are also more diversified than those in the Northern zone area. Notwithstanding, the post hoc analysis indicates that Southern zone and Middle zone did not show any statistically significant difference, though both areas were statistically significantly higher than those from the Northern zone. Again, this could be as a result of the availability of several alternative livelihood activities found more in the Middle and Southern locations of the region, which gives the opportunities to farms found in those areas to access other means of livelihoods.

Factors Constraining Maize farming Enterprises in the Volta Region

Maize production and the associated income in Ghana, including the Volta Region, continue to decline (MOFA, 2013). The study therefore seeks to identify and rank production and postharvest constraints of maize farmers in the region. This is to provide empirical evidence of Maize farming and the constraints facing maize farmers in the Volta Region. The outcome of the study will influence policy to better direct interventions to supporting the farmers to raise their productivity and incomes. The production and post-harvest constraints of maize are related to policy, infrastructure, use of information, communication technologies, financial marketing, pest and disease, land administration and tenure, innovations challenges among others. The results of production factors constraining maize enterprises in the Volta Region is presented in Figure 3 while the postharvest constraints are presented in Table 21.

Undercapitalization

Undercapitalization with a mean score of 60 was ranked the most pressing production constraint of maize farmers in the Volta Region. The result indicates the fact that finance to purchase inputs or investment in the Maize farming is a major challenge faced by farmers in the Volta Region. Undercapitalization results in poor or late land preparation, use of viable and proven farm inputs such as seeds and agrochemicals. Similar study in Kenya indicate factors such as proceeds from sale of farm produce including maize served as funds for increasing maize production (Ndwiga et al., 2013). Maize farmers need to widen their sources of income including non-farm income to assure food security and farm investments (Reardon, 1997). Improving farmer savings culture and insurance schemes also need to be critically addressed in dealing with the issue of undercapitalization among maize farmers in the Volta Region of Ghana.

Figure 3: Production factors constraining maize enterprises in the Volta Region

Source: Field survey, Akaba (2018)

High cost of inputs

High cost of inputs with mean score 56 was the second pressing highest constraint of farmers in the Maize farmers. Due to the increasing inflation rate in Ghana, the cost of inputs for maize production continues to increase. Moreover, due to long distances of the Volta Region from major cities of Ghana, there is a high transaction cost associated with input acquisition which also translates to increasing the cost of inputs used by the farmers. Due to the high cost of inputs, farmers either do not use the inputs at the recommended quantities or dosage to increase their yield. This finding is similar to findings of Komarek et al (2017), who found a negative association between fertilizer prices, use, area cultivated and income of maize farmers in central Malawi. The authors suggested a 52% increase in the income of smallholder maize farmers if fertilizer prices become zero. Kwaghe et al. (2014), Wada et al. (2005), Tashkalma et al. (2010) and Zalkuwi (2012) also found high cost of farm inputs to have negative effect on efficient of farm production.

Low yield

Abass et al., (2013) cited changes in weather (40%), field damage (33%) and storage pests (16%) as important factors causing poor crop yields leading to food losses. This study found Low yield with a mean score of 54 obtained from production as the third (3rd) most important production constraint affecting maize farmers in the Volta Region. Low yield stemming from low productivity from low capital investment in the farms have been major constraint to farmers in the Volta Region. Low yield negatively affect the income of farmers and the quality of life and inability to meet households needs, particularly food security (Abass et al., 2013).

Difficulty in accessing credit

Difficulty in accessing credit with a mean score 51 was the fourth ranked constraint of farmers in the Volta Region. Poor access to credit by farmers in Ghana is a bane to agricultural development and productivity. Maize farmers in the Volta Region are also plagued with major constraint of accessing credit. Apart from government, donor and Non-governmental support to farmers, private organizations have hitherto shun away from offering credit facilities to farmers. Primary reason for this is the consequence of high default rates by farmers as result of high risks associated with farming combined with farmers own attitude of loan/credit acquisition and repayment.

Awunyo-Vitor and Al-Hassan (2014) similarly found that poor access to credit has adverse effect on input use and productivity particularly among smallholder farmers.

Disease infection

Maize disease infection of farmers in the Volta Region was ranked the fifth constraint. This has Garrett mean score of 49. Maize diseases infection also affects farmers greatly in the Volta Region making them unable to achieve the expected yield and income. It is important that pesticides are made available to farmers at affordable prices. It is also crucial to scale up extension service delivery to increase the capacity of farmers in the Volta Region to better respond to disease control needs of their farms.

Difficulty in accessing labour

Difficulty in accessing labour for maize production mean score 48 is the sixth constraint ranked by farmers in the Volta Region of Ghana. Gulati et al. (2005) indicated that the higher cost of labour is a challenge in agricultural production. Labour to undertake the various farm operations/activities in maize production such as land preparation, farm maintenance (weeding, fertilizer, disease and pesticide control etc.) and postharvest operations is challenging in the Volta region. This could be attributed to migration of the youth to other areas and activities for higher incomes. Moreover, the cost of accessing labour is also high hence; farmers are unable to pay for their services. In a similar study in Kenya, it was found out that, those household members over 60 years of age were found to be engaged in Maize farming mostly on full time bases on their farm (Ndwiga, et al., 2013). This buttressed the migratory nature of the youth expected to engaged in farming and agricultural labour provision. There is a need for government to give incentive the youth to provide labour services.

Pest infestation

Pest infestation of maize production in the Volta Region with a mean score of 46 is seventh ranked constraint by farmers. Pest infestation has negative effect on maize production in the Volta Region of Ghana. Pests such as birds, rodents, worms, weevils among others heavily plagued maize production in the region. According to Abass et al. (2013), pest cause 15% (field), 13-20% (during processing) and 15-25% (storage) losses hence pest if left uncontrolled could result high reduction in yield. The recent incidence of invasive species like the fall armyworm (FAW) in maize has worsen the plight of farmers in dealing with pest in the study area. This constraint then needs to be controlled in order for maize farmers in the Volta Region to attain the needed outcome for engagement in the maize production venture. Best approach in dealing with pest situation is the Integrated Pest Management (IPM). This should be done with a blending of indigenous pest management knowledge and modern innovative technologies that are economically, environmentally and socially sustainable. Related issues pertaining to provision of farmers with biological and ecological information necessary to develop better pest management through experimentation need addressed by Research and Extension as well as policy (Abate et al., 2000).

Insufficient extension services

Insufficient extension services with a mean score 45 is the eight ranked constraint of farm farmers in the Volta region. Efficient extension service delivery results effective adoption of technologies for improving productivity stemming from undertaking the required cultural practices in maize production. In Ghana, the extension officer to farmer ratio is very high, and Volta Region is no exception. Therefore, since farmers are unable to access adequately the services of extension officers, activities that contribute to attaining high productivity in maize production is on the decline. This innovation could support maize farmers to deal with a majority of their challenges in the Volta Region.

Difficulty in controlling weed

Difficulty in controlling weeds with a mean score 44 is the ninth ranked constraint of farmers in the Volta Region of Ghana. Weed in a maize production is of major concern to maize-farming households in the Volta Region. Weeds such as *Chromolaena odorata* (acheampong weed), grasses, and witch weed are of great importance to maize production in the region. Another weed of immense economic importance is Striga. Striga usually attaches itself to the cereals such as maize or sorghum roots from which it draws its moisture and nutrient requirements, resulting in reduced plant growth, reducing yields, and in extreme cases leading to plant death (Ndigwa, 2013). Factors which contribute to the difficulty in weed control in maize production found by the study were the drudgery associated with the use of conventional tools like cutlass and hoe in weed control. Moreover, cost and availability of farm machinery as well as weedicides have made weed control a major concern in maize production. Due to the above challenges, farmers in the region engage practices such as bush burning, slush and burn amongst others, which have shown devastating effects on soil productivity to support plant growth and yield.

Difficulty in acquiring certified seeds

Difficulty in acquiring certified maize seeds with a mean score 43 is the tenth ranked constraint of farmers in the Volta Region of Ghana. The use of farmer own seeds for several seasons have negative implications on the yield potential of the seeds. Lack or inadequate availability of certified seeds have resulted in farmers using their own seeds in the Volta Region leading to poor to average outputs. Some organizations such as Africare and private input dealers have done their best to improve on the acquisition of certified seeds by farmers. Farmers however have cited high cost and timely availability of the seeds as reasons why certified seeds are not acquired and used. the major limitations to the rapid dissemination of newly released varieties included the unavailability of seeds in a commercial quantity, lack of awareness of available varieties and hybrids, lack of access to credit facilities by farmers, and the high relative price of seed.

Tahirou et al., (2009) also found monopolistic distribution of seeds through a single intermediary, slow reimbursement of seed credit sales, difficulty in getting access to other maize seed buyers, and low demand from farmers' lack of awareness were identified as factors affecting certified seed acquisition. Besides inaccessibility to rural areas due largely to the poor roads, preventing extension staff from getting to the rural communities, poor promotion and marketing efforts, high prices, and the inability of farmers to purchase complementary inputs, especially fertilizer also affect access to certified seed.

Land tenure insecurity

Land tenure insecurity is the eleventh ranked constraint of farmers in the Volta Region of Ghana. This constraint has mean score 41. Land security supports continuous cropping of the land for profit maximization by farmers. Arable land for cultivation of crop was not readily available to migrant farmers. In situations where land was available in the region, contractual agreements have not been respected particularly with respect to owners at the detriment of renters (farmers). Land tenure security influences land development regarding ownership, use and improvements (Dlamini & Masuku, 2011). As corroborated by Gulati et al. (2005), farmers are confronted with challenges regarding the use of marginal lands due to scarcity of cultivated lands. It is important to improve tenure systems in the Volta Region to increase maize outputs and productivity.

Low quality seeds

Low quality seeds with mean score 39 is the least (12th) constraint ranked by farmers in the Volta Region. Since farmers use their own source of seed often, seeds lose their potency with respect to germination percentage, growth rate, response to agricultural inputs and yield. Wambugu et al., (2012), indicated though on-farm seed production appears to have its constraints that lead to reduced yield and quality of farm-saved seeds, its strengths such as the presence of local varieties which are able to perform well under conditions of stress need to be retained while incorporating others from the formal seed sector such as timely harvesting and fertilizer application. It is important certified seeds are made available, accessed and used by farmers in the Volta Region.

Unremunerated maize prices

Unremunerated maize output prices is the most pressing need of farmers in the Volta Region of Ghana with a mean score of 58 (Table 21). Good prices are incentives for farmers to move into the maize farming. Due to low maize prices, farmers are unable in most cases to realize the production cost making them unable to make profit to meet their consumption needs and for savings and investments. This disincentive of unrenumerative prices of produced maize deters farmers to expand their farms or ensure productivity to attain higher profit. One other challenge associated with pricing of the maize is the lack of adherence to standard measurement by buyers. They often measure in excess of the agreed mode of measurement such as weight and grain size, thereby cheating farmers. This phenomenon is a great worry to farmers who could do little than to give in to the dictates of the buyers. It is important standards with corresponding output prices are closely adhered to in the Volta Region of Ghana. Kaminski et al. (2013) indicate that more remunerative prices for producers and improved standards, greater intra-regional maize trade stimulates public and private investments in research, marketing, agricultural services and infrastructures.

Table 21: Ranked Postharvest constraints of Maize farmers in the Volta Region

Constraint	1	2	3	4	5	6	7	n	Total score	Mean Score	Rank
Unremunerated maize prices	175	129	75	27	24	24	8	462	26416	58	1
High Postharvest losses	183	45	66	57	32	33	24	440	23651	54	2
Uncertain demands	91	132	59	33	31	36	18	400	21001	53	3
Inadequate storage facilities	63	130	101	83	29	11	17	434	21445	50	4
Lack of market information	39	51	101	56	45	19	16	327	15370	48	5
High transportation costs	57	65	58	65	54	39	24	362	16589	46	6
Lack of crop insurance	31	28	52	45	45	32	67	300	11425	38	7

Source: Field survey, Akaba (2018)

High postharvest losses

High postharvest loss with a mean score of 54 is the second postharvest challenge faced by farmers in the Volta region. High Postharvest losses continue to be constraint to maize farmers in the Volta Region. Farmers often harvest late leading to pest infestation from the field. Moreover, most farmers do have appropriate structures to store harvested maize is the lack of adherence to standard measurement by buyers. They often measure in excess of the agreed mode of measurement such as weight and grain size, thereby cheating farmers. This phenomenon is a great worry to farmers who could do little than to give in to the dictates of the buyers. It is important standards with corresponding output prices are closely adhered to in the Volta Region of Ghana. Kaminski et al. (2013) indicate that more remunerative prices for producers and improved standards, greater intra-regional maize trade stimulates public and private investments in research, marketing, agricultural services and infrastructures.

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Uncertain demands

Uncertain demands of maize by processors and consumers are ranked as the third most pressing challenge of maize farmers in the Volta Region of Ghana. This constraint has a mean score of 53. The study showed that farmers do not anticipate the required quantity of maize the market or consumers are willing to purchase. This phenomenon affects farmers either way if they either over or under produce which may result in reduction in income. Farmers therefore need to engage in contractual agreements to guarantee quantities and prices of maize prior to production.

Inadequate storage facilities

The fourth pressing Postharvest challenge of maize farmers in the Volta Region is the inadequate storage facilities owned by maize farmers in the Volta Region of Ghana. This has a mean score of 50. The study revealed that farmers are unable to acquire or develop spaces to store harvested produced. This study supports that of Gulati et al. (2005) that inadequate or nonexistence of storage facilities is having a dire consequence on agricultural production. This result in farmers engaging in distress sales at lower prices.

In cases where there have been attempts to store the maize, high pest: weevils, fungus, rodent attacks lead to heavy postharvest losses. Major stored product insects reported to cause damage in maize include *Sitophilus zeamais* were found by the study. Others such as *Rhyzopertha dominica*, *Prostephanus truncatus* and *Sitotroga cerealella* have also been found. Phosphine fumigation and application of pirimiphos-methyl were the primary insecticides used with considerable variations in how they have been used and little data regarding actual efficacy (Ndwiga et al., 2013).

Lack of market information

The fifth pressing challenge in postharvest ranked by farmers in the Volta Region is lack of market information. This constraint has mean score of 48. The study reveals that farmers in the Volta Region do not get information on which market to send their produce to for the right price and prompt purchases. Though it was realized that few farmers were on Esoko platform (a communications platform to help farmers and agribusiness enterprises manage agricultural value chains), the market information provided did not help since those markets were far off and farmers could not bear the transactional cost of marketing their produce. Application of Information Communication Technology (ICT) tools to enhance access to information is critical and need to be fully promoted in the Volta Region to connect buyers and producers. World Bank (2012) indicates that ICT use for instance mobile phones enhances marketing of goods related to price and location supply and demand access to inputs, diversification of product base among others. Government is expected to create marketing information centres in order to inform maize farmers on prevailing maize prices in the market (Ndwiga et al., 2013).

High transportation costs

High transportation cost with a mean score of 46 is the Sixth 6th postharvest constraint ranked by farmers in the Volta Region of Ghana. Due to unstable fuel prices, transportation cost continues to hike. Moreover, roads to farm gates and to markets centres are not motorable leading to transporters charging exorbitant prices to cart goods to the market. In certain conditions, goods are not taken to the market in good time leading to spoilage. Farmers' inclination to selling in bulk could reduce transportation cost associated with transporting their goods to the market. In cases of villages in remote areas where also maize was produced do not have accessible roads to motor vehicles, especially during the rainy season. In related studies, farmers in these villages use animal drawn carts to haul their products to the nearest market (Gerpacio, 2004). They resort to taxis, and where taxis are available, farmers need to keep the maize predisposing the grains to storage pest.

Lack of crop insurance

Lack of Crop insurance with a mean score of 38 is 7th and least constraint faced by maize farmers in the Volta Region of Ghana. Crop insurance as risk mitigating factor was found by the study to be lacking in the Volta Region. Insurance schemes against yield shortfalls are all lacking in the region. It is important stakeholders emphasize the development of insurance schemes to help farmers out of shocks. Insurance is crucial in unlocking credit for maize farmers through partnership between the insurance and banking firms as found by similar study in Indonesia (IFC, 2006). Hence, it is important Ghana need to learn from best practices to improve upon its insurance coverage for maize farmers in the Volta Region of Ghana. As indicated by Gulati et al. (2005) in the absence of insurance against risks associated with agricultural production will result in negative consequences on yields and livelihood security. Farmers therefore have resorted to managing such risks by engaging in enterprises that provide sustainable income and food security even if such activities are less productive (Nyikal & Kosura, 2005). They mostly tend to be inclined towards self-insurance strategies such as diversification and social mechanisms (Korir, 2011).

Table 22 shows rankings of production constraints by farmers across the three (3) divisions of the Volta region. The results indicate that undercapitalization is most severe in the Southern part of the region hence was ranked first (1) among the twelve items. The Northern and Middle sectors ranked the undercapitalization constraint as second (2). The results therefore suggest undercapitalization remain a major constraint of maize farmers in the Volta region.

While low yield is rated as 4th and 7th most serious problem in the North and Middle zone respectively, the southerners saw this to be the 2nd most important problem. Low yield at the southern zone could be as the result of continues cropping over the same piece of land as due to scarcity, south-ward migration and diverse alternative use for land by other sectors such as constructions and industries.

High cost of inputs remain the highest (1st) ranked constraint by farmers in Middle zone whereas it is ranked 3rd by farmers in the Northern and Southern zone. The high input cost continuous to affect the use and timely application of the agrochemicals. This has effects on productivity of the Maize farmers in the Volta Region. High transaction cost associated with input acquisition and provision by retailers and lack of subsidies could be a major contributory factor to the high cost of the inputs.

Table 22: Ranked production constraints of Maize farmers in the various sectors

Constraints	Geographical area											
	Northern				Middle				Southern			
	f	Total score	Mean Score	Rank	f	Total score	Mean Score	Rank	F	Total score	Mean Score	Rank
Undercapitalization	150	8821	58.81	2	157	8591	54.72	2	230	14802	64.37	1
Low yield	116	6275	54.09	4	83	3892	46.89	7	173	10045	58.06	2
Insufficient extension services	90	4001	44.46	11	101	4514	44.69	10	107	4905	45.84	7
High cost of inputs	189	10399	55.02	3	181	1061	58.62	1	204	11183	54.82	3
Difficulty in controlling weed	151	7008	64.41	1	79	3080	38.99	11	170	7699	45.28	9
Difficulty in accessing labour	127	6059	47.71	7	68	3657	53.78	3	144	6656	46.22	6
Disease infection	116	5759	49.65	6	71	3444	48.51	5	140	6829	48.78	4
Pest infestation	144	6634	46.07	9	115	5276	45.88	8	127	5768	45.42	8
Land tenure insecurity	69	3255	47.17	8	41	1970	48.05	6	93	3103	33.37	11
Difficulty in accessing credit	139	7184	51.68	5	69	3676	53.28	4	143	6975	48.78	5
Low quality seeds	46	2060	44.68	10	8	310	38.75	12	21	592	28.19	12
Difficulty in acquiring Certified seeds	80	3431	42.89	12	21	942	44.86	9	73	3024	41.42	10

Source: Field survey, Akaba (2018)

Difficulty in acquiring certified seeds is the least ranked (12th) constraint of farmers in Northern zone whereas it is ranked 9th and 10th in Middle and Southern Sectors respectively. The results thus suggest access to certified seeds is not of much of a challenge to a majority of maize farmers in the Volta Region. It is however recommended that access to the certified maize seeds is sustained and better improved to continually support maize production and livelihood of farmer in the Volta Region of Ghana.

Table 23 shows the extent to which maize farmers across the Northern, Middle and Southern Sectors of Volta Region rated postharvest constraints facing them. The results indicate that uncertain demands of maize by buyers were the major constraint across the Volta Region. A majority of farmers in the Northern and Middle parts of the region ranked it as the Highest (1st), whereas it was ranked second (2nd) in the southern part. The situation of under and over supply of maize by farmers has resulted in buyers not committing to contractual agreements in order to take advantage of the advantages of oversupply of maize and its associated price relationship. This phenomenon leaves farmers in a dilemma regarding the extent to which to produce or make arrangements for storage in situations of excess produce.

Unremunerated maize output prices remain the top most constraint ranked by farmers in Southern zone whereas it is ranked 4th and 3rd by Northern and Middle zone respectively. Since maize output is not high in Southern zone, it is primarily consumed by the locals hence affecting the price of the produce. Lack of crop insurance is the least ranked (7th) constraint by farmers in entire region (Northern, Middle and Southern).

Table 23: Ranked postharvest constraints of maize farmers in the Volta Region

Constraints	Geographical zones											
	Northern				Middle				Southern			
	f	Total score	Mean Score	Rank	f	Total score	Mean Score	Rank	f	Total score	Mean Score	Rank
Unremunerated prices	150	7910	52.73	3	102	4875	47.79	4	188	10866	57.8	1
High Postharvest losses	159	8409	52.89	2	133	7385	55.53	2	102	5207	51.05	3
Uncertain demands	170	9796	57.62	1	142	8391	59.09	1	147	8229	55.98	2
Inadequate storage facilities	170	8831	51.95	4	85	3920	46.12	6	177	8694	49.12	4
Lack of market information	144	6953	48.28	5	65	3027	46.57	5	111	5390	48.56	6
High transportation costs	150	6398	42.65	6	98	4807	49.05	3	110	5384	48.95	5
Lack of crop insurance	126	4937	39.18	7	78	2705	34.68	7	96	3783	39.41	7

Source: Field survey, Akaba (2018)

Though farm insurance has myriad of benefits to the farm sector of which maize production is exemption, farmers do not appreciate its importance to their farm development, risk minimization and profit maximization. The study shows non-existence of crop insurance in the Volta Region yet majority of farmers have minimal concerns regarding its negative implication on them.

Table 24: Number of production constraints farmers ranked in their enterprises

	Frequency	Percent	Cumulative Percent
0	34	4.6	4.6
1	19	2.6	7.2
2	33	4.5	11.7
3	94	12.8	24.6
4	135	18.4	43.0
5	125	17.1	60.0
6	96	13.1	73.1
7	38	5.2	78.3
8	22	3.0	81.3
9	13	1.8	83.1
10	16	2.2	85.3
11	60	8.2	93.5
12	48	6.5	100.0
Total	733	100.0	
Mean 5.54		SD	3.16

Source: Field survey, Akaba (2018).

More than three quarters of the farmers had at least four (4) productions constraining factors influencing their maize enterprises (Table 24). Majority (55%) had at least 5 constraints and 69% indicated 6 constraints. The results also indicate only few farmers (6.5%) were affected by all the 12 production constraints with 4.6% showing no challenge. That is a majority of farmers (95.6%) were confronted with production constraints in the Volta Region of Ghana.

Table 25: Number of postharvest constraints ranked by the maize farmers

	Frequency	Percent	Cumulative Percent
None	96	13.1	13.1
1	51	7.0	20.1
2	83	11.3	31.4
3	133	18.1	49.5
4	107	14.6	64.1
5	60	8.2	72.3
6	37	5.0	77.4
7	166	22.6	100.0
Total	733	100.0	
Mean	3.72	SD 2.37	

Source: Field survey, Akaba (2018)

Table 25 indicates that more than 64 percent of the maize-farming households had at least 4 out of the 7 postharvest constraints identified in the study area with 49% having 3 to 7 of the postharvest constraints faced by the farmers. Quite an appreciable number (22.6) of the farmers have as high as 7 constraints facing them. Conversely, the study found out that 13.1% of the farmers had no postharvest constraint confronting them.

The results in Table 26 indicate that about 2 out of every 10 farmers (19.5%) were faced with all the 12 constraints identified in the northern zone whereas no farmer had 12 constraints in both middle and southern zone. However, 22.6 percent had 11 constraints in the southern zone with middle (0.4%) and Northern (1.6%) negligible number of farmers with same number of farmers. Moreover, 23.4% farmers faced 4 production constraints in middle zone which is higher than farmers faced similar number of challenges in the Northern (16.3%) and southern zone (15.6%). The results also indicate that majority of the farmers across the region had at least six (6) production constraints confronting them: 41.2% for southern, Northern zone (63.1%) and Middle zone (85.3%) with the highest number of farmers who indicated at least 6 constraints. Farmers who showed no number of production constraints facing them were high in the northern region (8.1%) than middle (4.9%) and the southern sectors (0.8%).

Table 26: Geographical distribution of number of production constraints maize farmers faced in the Volta Region

Number	Geographical zones			Pooled
	Northern	Middle	Southern	
None	8.1	4.9	0.8	4.6
1	4.1	3.7	0.0	2.6
2	3.7	7.4	2.5	4.5
3	9.3	22.5	6.6	12.8
4	16.3	23.4	15.6	18.4
5	15.9	18.9	16.5	17.1
6	13.8	9.4	16.0	13.1
7	3.7	3.7	8.2	5.2
8	0.8	3.7	4.5	3.0
9	1.6	0.0	3.7	1.8
10	1.6	2.0	2.9	2.2
11	1.6	0.4	22.6	8.2
12	19.5	0.0	0.0	6.5

Source: Field survey, Akaba (2018)

The results from Table 27 indicate that as high as 20.5 percent of farmers did not have any post-harvest constraint in middle zone with 9.8 percent and 9.1 percent respectively not having any postharvest challenges in the northern and southern sectors. Conversely, 38.2 percent of the farmers have all postharvest constraints confronting them in the Northern sectors, followed by 22.6 percent in the southern sectors and as low as 7% in the middle sectors of the region. A majority of the farmers: Northern (49.6), Middle (67.3) and southern (60.8) sectors had at least 5 postharvest constraints confronting them.

Table 27: Distribution of number of postharvest constraints maize farmers face in the Volta Region

Number	Geographical zones			Pooled
	Northern	Middle	Southern	
None	9.8	20.5	9.1	13.1
1.00	7.7	9.4	3.7	7.0
2.00	4.5	10.7	18.9	11.3
3.00	15.9	19.3	19.3	18.1
4.00	15.0	17.2	11.5	14.6
5.00	6.5	10.7	7.4	8.2
6.00	2.4	5.3	7.4	5.0
7.00	38.2	7.0	22.6	22.6
Total	100.0	100.0	100.0	100.0

Source: Field survey, Akaba (2018).

A further analysis was also conducted to find out whether there were differences in the number of constraints facing the three geographical zones. This finding is presented in Table 28.

Table 28: ANOVA to find out if there are significant differences in the number of constraints maize farmers in the three geographical zones

		Sum of Squares	df	Mean Square	F	Sig.
Number of production constraints	Between Groups	851.643	2	425.822	48.117	.000
	Within Groups	6460.253	730	8.850		
	Total	7311.896	732			
Number of posharvest constraints	Between Groups	273.537	2	136.769	26.057	.000
	Within Groups	3831.688	730	5.249		
	Total	4105.225	732			

Source: Field survey, Akaba (2018)

As suggested by Field (2013) and Pallant (2005), Tamhene's T2 test was conducted for both production and postharvest constraints since Levene tests for equality of variance was found to be violated for the present analysis, $F(2,730) = 46.42$, $p = .000$ for production constraints and $F(2,730) = 7.06$, $p = .001$ for postharvest constraints. Owing to this violated assumption, equal variance not assumed heterogeneity was computed to show the multiple comparisons among the three Geographical zones. The results of the post hoc analysis is presented in Table 29. The results indicate that farmers in the middle zone (M = 4.11, SD = 2.02) experience fewer production constraints than those in the Northern (M = 5.82, SD = 3.76) and Southern zone (M = 6.71, SD = 2.89). Again, those farmers in the Southern zone experienced significantly higher number of problems than those in the Northern zone. Similarly, the Middle zone maize farmers had the least postharvest constraints than the rest of the areas.

Table 29: Mean comparisons of the number of constraints faced by farmers by zones

Geographical zones	f	Mean	Std. Deviation
	Number of production constraints		
Northern zone	246	5.8171[b]	3.75623
Middle zone	244	4.1066[a]	2.01765
Southern zone	243	6.7078[c]	2.88502
Overall	733	5.5430	3.16053
	Number of posharvest constraints		
Northern zone	246	4.3902[c]	2.46323
Middle zone	244	2.9139[a]	2.12877
Southern zone	243	3.8560[b]	2.26723
Overall	733	3.7217	2.36817

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

On the other hand, Southern zone had experienced less postharvest constraints than those maize farmers in the Northern zone. This could be due to the fact that Southern zone is close to two major national capitals (Lome and Accra) and the regional capital (Ho) where more organised and structured markets, and storage facilities can easily be found. It could also be the fact that the market demand for maize is high in the south where most of the population and transnational trade occur, unlike the north where they need to transport their commodities to the south or elsewhere before they could get ready markets. Therefore selling of produce and/or inputs acquisition for postharvest handling could be relatively more arduous in the North compared to the South.

Maize Production Sustainability in the Volta Region

Attitudes of maize farmers towards sustainable agriculture in the Volta Region

It is expected that farmers have attitudes, behaviours competencies and actions, which will ensure attainment of a greater goal in achieving sustainable development. In order to estimate production sustainability among the maize farmers, their attitudes towards sustainable agricultural practices were evaluated by exploring the degree of importance that farmers attach to different sustainable agricultural practices. As posited by Bergevoet et al. (2004), attitudes are defined as disposition to respond favourably or unfavourably to an object, person, institution or event. An attitude is (a) directed towards an object, person, institution, or event; (b) has evaluative, positive or negative elements; (c) is based on cognitive beliefs towards the attitude-object (i.e., the balancing between positive and negative attributes of an object leads to an attitude); and (d) has consequences for behaviour when confronted with the attitude object. Attitude is determined by the beliefs that are salient or important to a person. Attitudes are formed by what an individual perceives to be true about the attitude-object (Sadati, Fami, Asadi, & Sadati, 2010). According to Giraldi (2005) cited in Scare et al. (2015) attitudes have a motivational quality; indicating that attitudes drive the individuals to a particular behaviour or turn away from another.

Farmer's attitude was measured by using 13 attitudinal statements on sustainable agricultural practices. A 10 - point interval scale was used for this purpose. Score 10 was assigned to strongly agree statements, while 1 was assigned for strongly disagree statements respectively. Each respondent was asked to express her/his extent of agreement or disagreement by checking against any number from the interval of 1 to 10 levels of agreement types. In case of negative attitudinal statement, reverse score was assigned to each response. To classify the respondents on their attitude towards sustainable agriculture, the interval of standard deviation from mean was used (Sadati et al., 2010). Based on the computed scores the respondents were classified into four categories accordingly; i.e., very low attitude (up to 61.11 scores), low attitude (61.12 to 85.88 scores), high attitude (85.89 to 110.65 scores) and very high attitude (above 110.65 scores). Higher values designated positive attitude towards the practises of sustainable agriculture and lower values designate negative attitude towards the practises of sustainable agriculture. Other authors including Chouichom and Yamao (2010), Ghosh and Hasan (2013), Salawat et al. (2013), and Hasan, Ghosh, Arefin, and Sultana (2015) also used similar scale in their respective studies.

A low or very low level of measuring attitudes indicates negative attitudes toward sustainable agriculture while high or very high attitudes indicate positive attitudes towards sustainable agriculture. Table 30 shows that attitudes of 15.5 percent of respondents (f = 113) on sustainable agriculture was very low. In addition, 37.0 percent (f = 269) of respondents had low attitude and 28.5 percent of them (f = 207) had high attitude while 19.0 percent of them (f = 138) had very high attitude towards sustainable agriculture practices.

Table 30: Classification of farmers according to their attitude toward sustainable agriculture

	Geographical zones			Pooled
	North	Middle	South	
Very low	10.8	12.7	23.0	15.5
Low	35.8	32.8	42.4	37.0
High	25.4	32.0	28.0	28.5
Very high	27.9	22.5	6.6	19.0
Total	100.0	100.0	100.0	100.0
	ANOVA mean separations			
Mean	91.40^{a}	90.41^{a}	75.98^{b}	85.89
Standard deviation	25.26	24.13	21.84	24.77

Source: Field survey, Akaba (2018)

Key: Very low ≤ 61.11; Low = 61.12 – 85.88; High = 85.89 – 110.65

Very high ≥ 110.66

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

Delving into the geographical stretch of the region, the results indicate that majority of farmers from the North and Middle zone had either high or very high attitudes towards sustainable agriculture (53.3% and 54.5% respectively). Only about 35 percent of the farmers from the Southern part of the region had either high or very high attitudes towards sustainable agriculture. Thus, as high as two-thirds of the maize farmers from the South had very low or low attitudes towards sustainable agricultural practices. The mean attitudes from the various parts of the region also buttress this revelations, where Southern zone farmers had low mean attitude (mean ≐ 75.98) while those from the North and Middle zone were having high attitudes (mean = 91.4 and 90.4 respectively). Notwithstanding, the corresponding standard deviations indicate that the farmers in the region have wide levels of attitudes towards sustainable agriculture (SD ranging from 21.84 to 25.26). The post hoc analysis of the ANOVA also confirms the findings that those farmers from the North and Middle zone had statistically significantly higher attitudes than their counterparts from the South of the region. A study by Bagheri et al. (2008) show that farmers had good perception about sustainable technologies such as diversification, rotation and application of manure; but in general, they preferred modern technologies to local ones. Farmers also perceived agrochemicals as the best means to control pests and to improve production but their perception of intangible impacts of modern technologies was weak.

As posited by Pretty and Bharucha (2014), carbon content of soils is improved when legumes and shrubs are used, and when conservation agriculture increases the return of organic residues to the soil. Legumes also fix nitrogen in soils, thereby reducing the need for inorganic fertilizer on subsequent crops. The use of IPM also have seen reductions in synthetic pesticide use (Settle & Hama Garba, 2011; Pretty & Bharucha, 2014). In some cases, biological control agents have been introduced where pesticides were not being used at all, or habitat design has led to effective pest and disease management (Royal Society, 2009). Pretty and Bharucha (2014) reported that projects across sub-Saharan Africa, where nutrient supply is a key constraint, have used a mix of inorganic fertilizers, organics, composts, legumes, and fertilizer trees and shrubs to improve nutrient availability, in conjunction with conservation tillage to improve soil health.

Indicators used in measuring level of attitudes towards sustainable agriculture and perceived relative importance by maize farmers

The actions and inactions of farmers can have negative consequences, or otherwise, on economic, social and environmental sustainability. There were high response rate on all the indicators (number of respondents ranging from 704 to 727 out of the sample of 733 respondents). The lowest response rate was on the reduced nitrogen fertilizer rates (96.0%) while the highest response rates were on cover cropping, intercropping and crop rotation where 99.2 percent of the farmers gave their opinions on each of these indicators. The mean responses to the various items indicate that farmers have high level of attitudes on most of these items.

In the study, the attitudes towards sustainable agriculture in the Volta Region were measured on a score of 1 to 10 in terms of magnitude. The mean attitudes for the various indicators are presented in Table 31. The mean attitudes of farmers on the use of cover cropping, green manure and animal manure were above 7.5, which show high levels of attitudes of the farmers in favour of these indicators of sustainable agriculture. Farmers also show positive attitudes towards intercropping, biological control of weeds and pests and recycling of agricultural residues (Mean between 7.0 and 7.5). Crop rotation and reduced rates of herbicides had mean levels of above 6.5 but below 7.0 while reduced N_2 fertilizer rates, reduced use of fertilizer were having levels between 6.0 and 6.5. Integrated pest management was also rated to be around 5.8 while the least indicator of sustainable agriculture was reduced tillage (mean = 4.1).

According to Bagheri et al. (2008) farmers have negative perception toward some sustainable technologies, such as minimum tillage, reduced use of agrochemicals, mixed use of organic and chemical fertilizer, biologic and cultural control of pests.

Farmers' attitudes strongly favoured introduction of new crops, changes in crop varieties, and changes in planting times however, their attitude tend to disfavour soil, land, and water management practices (Shikuku, Winowiecki, Twyman, Eitzinger, Perez, Mwongera & Läderach, 2017).

The results also show some degree of variations in the views of the farmers with regard to their attitudes towards sustainable agricultural indicators. This is evident from the relatively wide standard deviations for all the indicators used (SD ranging from 2.54 to 3.68). However, the variations in the views of farmers could generally be seen to be widening up as the mean levels reduce. This is indicative of disagreements among the farmers on whether these indicators were indeed sustainable practices or not. These divergent views call for extended analysis to identify the sources of variations, more specifically within the various agro-ecological zones in the Volta Region.

The Kendall's coefficient of concordance was used to test the degree of agreement among maize farmers in the Volta Region on the relative importance of the sustainable agricultural practices (Table 31). This was done to estimate the sum of ranks for each of the indicators rated by individual farmers and then examine variability of this sum. As a statistical procedure, Kendall's coefficient of concordance is used to identify and rank a given indicator from most sustainable agricultural practice to the least sustainable practice.

From the results, cover cropping had the highest mean rank of 8.67. This implies that based on maize farmers assessment, it is the most important sustainable agricultural practice in the region. The second and third most important sustainable agricultural practices ranked by the maize farmers were the use of green and animal manures (W = 8.36 and 8.31 respectively).

Table 31: Level of attitudes towards sustainable agriculture by maize farmers

Sustainable practices	Descriptive Statistics			Mean Rank
	n	Mean	Std. Dev.	
Cover cropping	727	7.9849	2.54243	8.67
Use of green manure	724	7.5594	2.8094	8.36
Use of animal manure	722	7.6593	2.63766	8.31
Biological control of weed and pests	714	7.2157	2.86361	8.11
Recycling agricultural wastes	724	7.1285	2.93051	7.91
Intercropping	727	7.4099	2.5675	7.62
Crop rotation	727	6.9519	2.997	6.96
Reduced rates of herbicides	714	6.7227	2.93241	6.91
Reduced nitrogen fertilizer rates	707	6.3876	3.24098	6.55
Reduced use of fertilizers	717	6.357	3.12151	6.51
Integrated pest management	722	5.8213	3.42301	5.88
Row banding of herbicides	721	5.3162	3.46689	5.20
Reduced tillage	720	4.125	3.67807	4.01

Kendall's W Statistics	
N	682
Kendall's Coefficient of Concordance	.162
Chi-Square	1329.34
Df	12
Asymp. Sig.	.000

Source: Field survey, Akaba (2018).

Biological control of weeds and pests was the next most important practices followed by recycling of agricultural waste, intercropping, crop rotation, reduced agrochemical rates and integrated pest management, in that order. The least sustainable practice indicated was reduced tillage and row banding of herbicides. The results show considerably low degree of agreement among maize farmers given the fact that Kendall's W was 0.162. Intuitively, there is low level of consensus among the maize farmers concerning the relative importance of what they perceived to be sustainable agricultural practices.

This could also be buttressed by the large standard deviations corresponding to the various indicators used in measuring the sustainability practices. This finding is not so surprising due to the fact that the sample size is relatively large and within such observations, it is not unexpected that different people may have divergent views on one topic or the other. Notwithstanding, this level of agreement on the sustainable agricultural practices is significant at 1 percent alpha level (χ^2 = 1329.34; df = 12, $p < .05$). The null hypothesis tested was that there is no agreement among maize farmers in the ranking of the sustainable agricultural practices indicators. The null hypothesis is rejected, showing that the respondents are in agreement with each other on the ranking of the sustainable agricultural practices. The finding implies that maize farmers in the study area agreed on the rankings of the indicators for sustainable agricultural practices. Therefore, the null hypothesis that there is no concordance among the farmers on the ranking of the attitudes toward sustainable agricultural practices is rejected in favour of the alternative.

Relationship between farmers' attitudes towards sustainable agricultural practices and farm- and farmer characteristics

The correlation analysis of attitude toward sustainable agriculture with selected socio-economic variables was performed. This was done to check for those predictor variables that have statistically significant association with the dependent variable (attitudes towards sustainable agricultural practices). The correlations results (Table 32) were also useful in checking for multicollinearity. Thus if any two explanatory variables have a coefficient of 0.80 or greater there may be cause for concern – they may actually be measures of the same underlying factor. The results for the correlations indicate that there was no multicollinearity in the independent variables (Strand, Cadwallader, & Firth, 2011; Field, 2013).

According to Table 32, there are statistically significant and negative associations between age of respondents and number of sources of agricultural information with attitude toward sustainable agriculture. In addition, there are positive significant relationships between attitudes toward sustainable agriculture with variables such as: sex, marital status, number of years in education, crop diversification, land size, yields and use of own land for farming.

Other variables, which did not show any significant correlation with the attitudes towards sustainable agriculture, include experience in Maize farming activities and membership to farmer associations which have negative and positive relationships respectively. Bagheri et al. (2008) also found relationships between a numbers of socio-economic factors (such as human capital factors, information sources use, extension participation and landholding size) and the perception towards selected sustainable agricultural technologies.

Table 32: Correlation between attitude toward sustainable agriculture and selected socio-economic variables

Variables	Attitudes	1	2	3	4	5	6	7	8	9	10	11
Sex (1)	.201**											
Age (2)	-.077*	-.025										
Marital status (3)	.090*	.190**	.008									
Years in formal education (4)	.125**	.197**	.001	.053								
Household size (5)	.121**	.156**	.157**	.181**	-.027							
Crop diversity (6)	.135**	.102**	.090	.231**	.103**	.153**						
Number of sources of technical information (7)	-.142**	.042	-.049	.121**	-.044	.043	.039					
Land size (8)	.216**	.103**	.080	.131**	.108**	.358**	.172**	.055				
Yield (9)	.228**	.143**	.061	.152**	.102**	.284**	.223**	.025	.729**			
Year of growing maize (10)	-.037	.058	.587**	.095*	-.052	.160**	.009	.019	.181**	.074*		
Farmer associations (12)	.028	.024	.022	.020	.131**	.001	-.053	.003	.022	-.019	.050	
Own land (13)	.099*	-.048	.057	-.132**	-.006	.056	.126**	-.096*	.020	.107**	-.097*	-.03[illegible]

Source: Field survey, Akaba (2018)

*Significant at 0.05 alpha levels

**Significant at 0.01 alpha levels

Farm- and Farmer-Specific Determinants of Attitudes towards Sustainable Agriculture in the Volta Region

The attitude of farmers towards sustainable agriculture differs from farmer to farmer and is influenced by socio-economic characteristics as well as information seeking behaviour of the farmers (Tatlidil et al., 2008). Table 33 presents selected farm- and farmer-related variables that influence the attitudes toward sustainable agriculture. This was accomplished using multiple regression analysis. Of the 12 variables entered, only 2 variables (sex and number of sources of technical information) had significant influence on farmers' attitude at $p < 0.01$ while one item (age of respondent) was significant at 0.05 alpha levels. Another two (land size and own land) were significant at 10 percent alpha levels. All the variables together explained only 14.0 percent of the variance in maize farmers' attitudes toward sustainable agriculture in the Volta Region. Similar results were reported by Sadati et al., (2010) that extension contacts and literacy have positive influence on farmers' attitudes towards sustainable agriculture. In other studies conducted with farmers to study their attitudes toward sustainable agriculture, it is pointed out that farmers who are older, with some amount of experience in agriculture, family size and more land, had low attitude to sustainable agriculture than younger farmers. However, farmers with high literacy level and participation in extension courses have a high levels of attitudes toward these practices (Sadati, Fami, Asadi, & Sadati, 2010; Scare, Neves, Bara, Simprini, & Castro, 2015). As argued by Ajzen (2001) and Scare et al. (2015), having strong attitudes are characterized by factors including stability over time, endurance and ability to predict behaviour.

Table 33: Results of multiple regression analysis of farm- and farmer-specific determinants of level of attitudes toward sustainable agriculture

Model	Sum of Squares	df	Mean Square	F-ratio	Sig.
Regression	65.945	12	5.495	7.157	.000
Residual	406.175	529	.768		
Total	2.120	541			

Variables in the equation

Model	Unstandardized Coefficients		t	Sig.	Collinearity Statistics	
	B	Std. Error			Tolerance	VIF
(Constant)	2.1012	0.2087	10.0680	.000		
Sex	0.3347	0.0931	3.5951	.000	.894	1.118
Age	-0.0079	0.0037	-2.1351	.034	.619	1.615
Marital status	0.0951	0.1063	0.8946	.372	.860	1.163
Years in formal education	0.0114	0.0088	1.2954	.197	.909	1.100
Household size	0.0088	0.0113	0.7787	.436	.812	1.232
Crop diversity	0.0629	0.0404	1.5569	.121	.870	1.150
Source of technical information	-0.0807	0.0206	-3.9175	.000	.969	1.032
Land size	0.0194	0.0102	1.9020	.057	.422	2.370
Yield	0.0034	0.0024	1.4167	.154	.442	2.263
Year of growing maize	-0.0011	0.0048	-0.2292	.894	.598	1.672
Farmer associations	0.5301	0.8907	0.5952	.552	.972	1.028
Own land	0.1574	0.0822	1.9148	.056	.912	1.096

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.374[a]	.140	.120	.87625	1.252

Source: Field survey, Akaba (2018)

These characteristics relate differently according to formation, gender, age and race, highlighting the notion that attitude is a unitary construction. The strength of attitudes can vary over the person's life cycle with greater strength in mid-life.

In other studies conducted with farmers to study their attitudes toward sustainable agriculture, it was pointed out that farmers who are older, with high experience in farming, large family size and more land had low attitude to sustainable agriculture than younger farmers. However, farmers with high literacy level and participation in extension courses have a better attitude toward these practices (Sadati et al., 2010).

Since neither of the predictor variables has a variance inflation factor (VIF) greater than ten (VIFs ranging from 1.028 to 2.370), there are no apparent multicollinearity problems; in other words, there is no variable in the model that is measuring the same relationship/quantity as is measured by another variable or group of variables (Field, 2013; Sarstedt, Ringle, & Hair, 2017).

A One-way between-group analysis of variance (ANOVA) was conducted among the three geographical zones on the level of agreement on the sustainable agricultural practices. The results presented in Table 34 indicate that apart from intercropping, crop rotation and IPM, all the sustainable agricultural practices showed significant differences in the perceptions of farmers in the three geographical zones in the region. This means that the issues or views of farmers about whether intercropping, crop rotation and IPM contribute to sustainable agricultural practices were relatively similar among the farmers from Northern, Middle and Southern zone. The results imply that irrespective of the geographical area that the farmers were, they have similar levels of agreement on these three indicators for sustainable agricultural practice. However, there were significant differences in the views of the farmers on the other sustainable agricultural practices.

Table 34: One-way between-group ANOVA among the Geographical zones on the level of agreement on the sustainable agricultural practices

		Sum of Squares	df	Mean Square	F	Sig.
Intercropping	Between Groups	29.142	2	14.571	2.218	.110
	Within Groups	56.706	724	6.570		
	Total	85.849	726			
Cover cropping	Between Groups	289.434	2	144.717	23.875	.000
	Within Groups	4388.429	724	6.061		
	Total	4677.862	726			
Crop rotation	Between Groups	36.956	2	18.8	2.133	.119
	Within Groups	6272.359	724	8.663		
	Total	6309.315	726			
Row banding of herbicides	Between Groups	92.570	2	46.285	3.882	.021
	Within Groups	8561.330	718	11.924		
	Total	8653.900	720			
Integrated pest management	Between Groups	54.984	2	27.492	2.355	.096
	Within Groups	8392.968	719	11.673		
	Total	84.952	721			
Use of green manure	Between Groups	939.335	2	469.667	71.035	.000
	Within Groups	67.111	721	6.612		
	Total	5706.446	723			
Use of animal manure	Between Groups	372.953	2	186.7	28.876	.000
	Within Groups	4643.229	719	6.458		
	Total	5016.183	721			
Reduced rates of herbicides	Between Groups	87.108	2	43.554	5.124	.006
	Within Groups	6043.985	711	8.501		
	Total	6131.092	713			
Reduced nitrogen fertilizer rates	Between Groups	244.429	2	122.214	11.998	.000
	Within Groups	7171.382	704	10.187		
	Total	7415.810	706			
Reduced use of fertilizers	Between Groups	123.676	2	61.838	6.443	.002
	Within Groups	6852.921	714	9.598		
	Total	6976.597	716			
Reduced tillage	Between Groups	272.181	2	136.090	10.321	.000
	Within Groups	9454.569	717	13.186		
	Total	9726.750	719			
Recycling agricultural wastes	Between Groups	6.668	2	323.834	41.983	.000
	Within Groups	5561.386	721	7.713		
	Total	6209.054	723			
Biological control of weed and pests	Between Groups	757.767	2	378.883	52.935	.000
	Within Groups	5089.018	711	7.158		
	Total	5846.784	713			
Level of agreement	Between Groups	226.026	2	113.013	34.715	.000
	Within Groups	2356.934	724	3.255		
	Total	2582.960	726			

Source: Field survey, Akaba (2018)

Measures of Homogeneity of Variance

To satisfy the assumptions associated with the running of analysis of variance (ANOVA), homogeneity of variance test statistics was conducted on the level of attitude of farmers on sustainable agricultural practices (Appendix D). The homogeneity of variance assumes that the variance of one variable is stable (i.e. relatively similar) at all levels of another variable (Field, 2013). Levene's Test for the equality of variances was carried out to determine the variances in the mean levels of agreement on the sustainable agricultural practices within the three geographical zones.

The findings presented in Appendix D reveal that the Levene's tests of equality of variance indicated that row banding of herbicides, reduced rates of herbicides and reduced nitrogen fertilizer rates have alpha levels of significance greater than the 0.05 and hence implies that the assumptions of homogeneity of variance has not been violated for these variables. As recommended by Pallant (2005), the non-significant figures are indicative of non-violation of homogeneity of variance assumptions employed in the ANOVA. However, the other sustainable agricultural variables (cover cropping, intercropping , row banding of herbicides, integrated pest management, use of green manure, use of animal manure, reduced use of fertilizers, reduced tillage, recycling agricultural wastes, and biological control of weed and pests) showed significant differences in the variances among the three geographical zones.

Table 35 shows the results of the post hoc of the one-way between-groups analysis of variance (ANOVA) that were conducted to determine the effect of different geographical zones on the selected variables which did not violate the assumptions of homogeneity of variance. As suggested by Field (2013) and Pallant (2005), Duncan's multiple range tests were conducted for those variables with homogeneous variances (equal variance assumed) while Tamhene's T2 test was also conducted for those variables that did have heterogeneous variances (equal variance not assumed).

Table 35: Post hoc analysis of the sustainable agricultural practices among the farmers in the different Geographical zones in the study area

Practices	North	Middle	South
Intercropping	7.54	7.56	7.13
Cover cropping	8.50	8.37	7.10
Crop rotation	7.20	7.00	6.65
Row banding of herbicides	5.54[a]	5.60[a]	4.81[b]
Integrated pest management	5.73	6.19	5.54
Use of green manure	8.44[a]	8.30[a]	5.96[b]
Use of animal manure	8.17[a]	8.17[a]	6.65[b]
Reduced rates of herbicides	7.14[a]	6.74[ab]	6.28[b]
Reduced nitrogen fertilizer rates	7.02[a]	6.54[a]	5.60[b]
Reduced use of fertilizers	6.48[a]	6.79[a]	5.80[b]
Reduced tillage	4.69[a]	4.41[a]	3.27[b]
Recycling agricultural wastes	7.84[a]	7.77[a]	5.80[b]
Biological control of weed and pests	7.99[a]	7.92[a]	5.78[b]
Mean level of agreement	7.10[a]	7.03[a]	5.89[b]

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

The findings from Table 35 show the mean separation among the maize farmers from the various geographical zones in the Volta Region. Row banding consists of spraying herbicides only over the plant rows either at the time of planting, pre-emergence or post-emergence of the crop. Weeds in the space between the rows are controlled mechanically when the plants reach a certain height. Then vegetative growth of the plant covers the spacing between the rows, thus preventing further weed growth.

The mean levels of attitudes of farmers towards sustainable agricultural practice from the Middle and Northern zones were significantly higher than their counterparts from the south. As posited by Jean (2017), herbicide banding has a number of environmental and economic benefits. This allows for reduction in production costs; risk of contaminating waterways and water tables; risks to human health and the environment; and risk of weeds developing resistance to herbicides. The use of green and animal manures, reduced nitrogen fertilizer rates, reduced use of fertilizer, reduced tillage, recycling agricultural wastes, and biological control of weed and pests also had similar differences in the opinions of these categories of farmers where those from the Middle and Northern zones had similar views but those from the Southern zone had statistically significant divergent views in terms of their level of agreement.

The result of how farmers' attitudes toward sustainable agricultural practices influence their own production sustainability is presented in Table 36. The use of animal manure, reduced rate of nitrogen fertilizer, reduced tillage and biological weed and pests control were significant in predicting the farmers own production sustainability. These significant variables, except reduced tillage, had positive relation with sustainability index. Thus an increase in the opinions towards these indicators for sustainable agricultural practices could positively have influence the farmers' ability to practise production sustainability in their maize farms. The regression estimates show that reduced tillage had negative relationship with sustainability index, which implied that farmers who have high attitudes toward reduce tillage contribute to agricultural sustainability rather use unsustainable methods in their maize production. This could be due to the fact that though they are perfectly aware of its contribution to sustainability, other factors such as vegetation, appropriate inputs, technical expertise and indigenous practices were prohibiting them from practicing sustainable production activities. These revelations corroborates the responses farmers gave about the bottlenecks of sustainable agriculture during the field survey.

Table 36: Effect of farmers' attitudes toward sustainable agriculture on maize production sustainability of farmers in Volta Region

ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.654	13	.050	5.045	.000
Residual	6.658	668	.010		
Total	7.312	681			

Variables in the equation

Model	Unstandardized Coefficients*		t	Sig.	Collinearity Statistics	
	B	Std. Error			Tolerance	VIF
(Constant)	0.4472	0.0159	28.1248	.000		
Intercropping	-0.0016	0.0015	-1.0667	.317	.680	1.1
Cover cropping	0.0060	0.0032	1.8749	.060	.381	2.625
Crop rotation	0.0002	0.0021	0.0956	.923	.7	2.097
Row banding of herbicides	0.0034	0.0021	1.6203	.103	.500	1.998
Integrated pest management	-0.0006	0.0009	-0.6567	.531	.570	1.754
Use of green manure	-0.0028	0.0024	-1.1665	.244	.327	3.058
Use of animal manure	0.0045	0.0019	2.3685	.020	.0	2.127
Reduced rates of herbicides	-0.0022	0.0017	-1.2939	.196	.516	1.938
Reduced nitrogen fertilizer rates	0.0047	0.0021	2.2381	.026	.435	2.297
Reduced use of fertilizers	-0.0017	0.0022	-0.7734	.433	.443	2.259
Reduced tillage	-0.0034	0.0011	-3.0908	.014	.567	1.765
Recycling agricultural wastes	0.0020	0.0017	1.1765	.237	.539	1.854
Biological control of weed & pests	0.0063	0.0020	3.1498	.002	.495	2.022

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.299	.089	.072	.09983	1.442

Source: Field survey, Akaba (2018)

*The dependent variable is maize production sustainability.

Sustainable production practices increase crop productivity and diversify food production, while simultaneously restoring and enhancing natural capital and ecosystem services (FAO, 2016). This is done by achieving higher rates of efficiency in the use of farm inputs such as water, soil nutrients and labour, and strengthening resilience to abiotic, biotic and economic stresses, and to climate change.

Production sustainability offers a range of productivity, socio-economic and environmental benefits to smallholder farmers and to society at large, including: high and stable production and profitability; higher farmer income and improved rural livelihoods; increased availability and consumption of the diverse range of foods necessary for a healthy diet; adaptation and reduced vulnerability to climate change and other shocks; enhanced ecosystem functioning and services; and reductions in agriculture's greenhouse gas emissions and carbon footprint (FAO, 2011; 2016).

Practices of Sustainable Maize Production among Farmers in the Volta Region

FAO (1993) contended agriculture must not degrade the environment but it needs to be technically appropriate, economically viable and socially acceptable. To ensure environmental, economic, and social sustainability, farmers must adopt different farm-level practices such as judicious use of chemicals, integrated pest management, adequate irrigation, and proper care of plant and animal health (Sadati, Fami, Asadi, & Sadati, 2010). This study therefore delved into the environmental, economic and social sustainable practices among the maize farmers in the Volta Region.

The results in Table 37 indicate that less than 20 percent of the farmers used conservation tillage during their maize production. Looking at the geographical distribution of farmers, the highest proportion of farmers who practise conservation tillage were those from the Middle zone and this is less than a third of them (29.1%).

Table 37: Percentage distribution of farmers who practiced sustainable maize production

Indicators	North	Middle	South	Pooled
Environmental				
Land preparation	9.8	14.8	0.4	8.3
Use of organic manure	11.8	7.8	28.0	15.8
Weeding	51.6	27.9	64.6	48.0
Usage of stubbles	75.6	83.6	90.1	83.1
Changing trend in soil resources	55.3	40.6	41.6	45.8
Weedicides usage	85.4	70.9	62.1	72.9
Pesticides usage	98.8	98.0	95.5	97.4
Fungicides usage	98.4	100.0	99.2	99.2
Nitrate application	60.6	41.4	39.5	47.2
Conservation tillage	21.1	29.1	6.6	19.0
Mean environmental sustainability	***56.8***	***51.4***	***52.8***	***53.7***
Social				
Access to extension services	63.4	57.8	56.0	59.1
Access to labour	.6	72.1	40.7	53.5
Land tenure security	72.0	83.2	61.7	72.3
Access to improved seeds	67.1	91.4	70.0	76.1
Age of farmer	89.0	91.0	91.8	90.6
Knowledge on fertilizer resource conservation	14.2	12.3	8.6	11.7
Knowledge on agro-chemical conservation	73.6	78.3	56.0	69.3
Mean social sustainability	***61.0***	***69.4***	***55.0***	***61.8***
Economic				
Number of seeds per hill	92.3	70.9	93.0	85.4
Planting in rows	79.7	77.0	62.6	73.1
Alternative livelihoods	30.5	37.3	42.4	36.7
Formal and regular source of income	5.3	15.6	6.2	9.0
Crop diversification	82.9	73.0	66.7	76.0
Average yield per hectare	24.4	15.2	9.5	16.4
Mean economic sustainability	***52.5***	***48.2***	***46.7***	***49.4***

Source: Field survey, Akaba (2018)

For those from the Northern zone, only about 1 out of every 5 farmers practised conservation tillage while less than 7 percent of farmers from the Southern zone were involved in conservation tillage. Soil has the potential to store huge amounts of carbon. Every time soil is turned over, large amounts of that carbon are released into the atmosphere. In addition, tilling the soil has implications for soil structure formation, water retention and soil biodiversity (Grover, 2013). Practicing conservation agriculture like no-tillage farming will therefore reduce the amount of carbon released to the atmosphere from the soil. This will help reduce negative contribution of agriculture to climate change. The generally low level of conservation tillage practices among the maize farmers will therefore reduce sustainability of agriculture.

Most of the farmers practised sustainable application of weedicides and fungicides. Observation from the field indicates that most farmers do not have the resources to acquire enough of these agro-chemicals, let alone misusing it, hence their ability to fall into the sustainable user group. These cut across the various geographical zones of the region similarly, at least 7 out of every 10 maize farmers in the region were sustainably using weedicides. There is however variations among the different geographical zones. For instance, while more that 4 out of every 5 farmers in the Northern zone practised sustainable weedicide application, only about 3 out of 5 farmers from the South were using weedicides on a sustainable basis and 7 out of 10 farmers from the Middle zone practised sustainable weedicides applications.

Another environmental sustainability that most farmers in the region are practicing is the use of stubbles or plant residues. At least 4 out of every 5 farmers have responded to the use of plant residues. At least three quarters of the farmers from the Northern part use plant stubbles to improve the fertility of the soil rather than burning or throwing them away, which could have inimical environmental consequences. More proportion from Middle and Southern zone use this sustainability method to improve soil fertility (83.6% and 90.1% respectively).

Other environmental indicators that substantial number of farmers practised include nitrate application (47.2%) and weeding (48.0%). Majority of farmers from the North of Volta practised these indicators (51.6% and 60.6% respectively). While at least 3 out of every 5 farmer from the South practiced sustainable weeding, a little less than 40 percent of them practiced sustainable nitrate application. Those farmers from the Middle zone were the least in practicing sustainable weeding (27.9%) and nitrate application (41.4%). The mean proportion of the maize farmers who farm on environmentally sustainable basis in the North was 56.8 percent, 51.4 percent from the Middle zone and 52.8 percent from the South. Majority of the farmers in the region are engaged in sustainable environmental practices.

The main indicators used to measure social sustainability include access to extension services, labour and improve seeds, land tenure security, age of farmer, and knowledge on fertilizer and other agro-chemical conservation. Social sustainability based on the age of the farmers tend to be the most sustainable indicator across the region. More than three-quarters of the farmers in the region were able to have access to improved seeds though this was most prominent in the Middle zone where more than 90 percent of them were able to have access to improved seeds. Only 70.0 percent and 67.1 percent of the farmers from the Southern and Northern sector of the region had access to improved seeds.

Land tenure security has implications for achieving sustainability of agricultural practices. The results reveal that 72.3 percent of the respondents had secured access to land. These farmers were either using their own land or are using family land which they are the heads of the family and are in control of the management of the land for the family. The results further indicated that more of those farmers from the Middle zone were having more secured land than those from the north and the south (83.2%, 72.0% and 61.7% respectively).

On the average, a little below 70 percent had knowledge on agro-chemical conservation while only 11.7 percent had knowledge on fertilizer resource conservation. Again, most farmers from the Middle zone have knowledge on agro-chemical conservation while about 74 percent of farmers from the Northern part and only 56 percent of those from the South had knowledge on agro-chemical conservation. Knowledge on fertilizer resource conservation ranges from 8.6 percent in the South to 14.2 percent in the North with only 12.3 percent of the farmers from the Middle zone having such knowledge.

In the case of access to extension services, around 60 percent of the farmers across the region had access though there were slight variations along the geographical stretch. For instance, while more than 3 out of every 5 farmer in the North had access to extension services, only 57.8 percent and 56.0 percent of the farmers from the Middle and Southern zones respectively had access to extension services. Access to labour tend to be an issue of social sustainability, more especially in the North and South of Volta where more than half of the farmers have challenges in accessing the services of labour in their farming activities. However, majority of the farmers in the Middle zone (72.1%) easily had access to labour. The average proportion of social sustainability in the Volta Region was about 62 percent. Obviously, almost about 70 percent of farmers from the Middle zone practised social sustainability while 61.0 percent from the North and only 55.0 percent from the South practised social sustainability.

While most of the farmers from the North and South used the appropriate number of seeds per hill, only 7 out of 10 farmers in the Middle zone sowed their maize on sustainable basis. About 80 percent of the farmers from Northern zone practised row planting 77 percent from Middle zone and 62.6 percent from the South also practised row planting. Majority of the farmers do not have alternative source of livelihoods. While only about 31 percent of farmers from Northern zone had alternative livelihood, 37.3 percent and 42.4 percent of respective farmers Middle and Southern zone had alternative livelihood. It could be observed that the ability to engage in alternative livelihood reduces as one moves from the south to the north of the study area. Only a few proportion of farmers were having formal and regular sources of income. As high as 95 percent of farmers in the North do not have any formal source of income. A similar number portion from the South (93.8%) also do not have formal sources of income. For those in the Middle zone, only 16 percent had regular sources of income

Table 38: Friedman rank tests for sustainability indices used for classifying of maize-farming households

Friedman Test Statistics for the mean ranks	EnvSus	SocSus	EcoSus
Means	0.537	0.618	0.491
St.Dev.	0.128	0.215	0.190
Mean rank	1.88	2.41	1.71
Total observation		733	
Chi-Square		198.236	
Degree of freedom		2	
Asymptotic Significance		.000	

Wilcoxon Signed Ranks Test Statistics			
	SocSus-EnvSus	EcoSus-EnvSus	EcoSus-SocSus
Z^a	-9.126	-5.468	-10.304
Asymp. Sig. (2-tailed)	.000	.000	.000

a. Based on positive ranks

Source: Field survey, Akaba (2018)

Overall, more than 90 percent of farmers in the Volta Region do not have regular sources of income. Most farmers in the Northern zone diversified their crop production enterprises. In the Middle zone, 73.0 percent of the farmers diversified their crops while two-thirds of those from the Southern zone diversified their crops. Less than a quarter of the maize farmers from the Northern zone who had sustainable productivity while only about 15 percent of those from the Middle zone had sustainable productivity and less than 10 percent from the Southern zone had sustainable productivity.

A Friedman test was conducted to assess if there were differences among the sustainability indicators among the maize farmers in the Volta Region of Ghana (Table 38). The chi-square, χ^2 (2, n= 733) = 198.236, p = .000 indicates significant differences among the economic (EcoSus), environmental (EnvSus) and Social (SocSus) sustainability indices, which were the main indicators used to measure production sustainability practices of the maize farmers. Base on the results, three orthogonal contrasts were performed using Wilcoxon Signed Ranks Test with the Bonferroni correction (comparison-wise alpha = .017) (Leech, et al., 2005). The contrast between social and environmental sustainability indices (Z = 9.126, p = .000), Economic and environmental sustainability indices (Z = 5.468, p = .000), and economic and social sustainability indices (Z = 10.304, p = .000) were all found to be significant.

In all cases, the significant contrasts indicate that the maize farmers are most sustainable in social indicators followed by the environmental sustainability with the least sustainable indicator being the economic sustainability index. Thus, considering the maize farmers' age, knowledge about fertilizer and other agro-chemicals conservation, access to resources such as seeds, extension services, labour and improved seeds; and land tenure security; the farmers in the Volta Region are more better of in their social sustainability than in their environmental considerations in the areas of land preparation, use of organic materials, agro-chemical usage such as pesticides and nitrate applications, and conservation tillage practices. On the other hand, the farmers' efforts in achieving optimum level of resource use and improving productivity in the maize enterprises, and engaging in alternative income generation activities did not result in eventual economic sustainability as compared to social and environmental indices. This indicates that, though the farmers are more knowledgeable of the agronomic practices that will help improve the sustainability of their production, putting this knowledge into practise is significantly lower than their access and knowledge.

Sustainable agricultural practices cannot be only economically viable, but also environmentally and socially acceptable. It also requires a long-term perspective and continuous activities over several generations (Scare et al., 2015). Thus, the performance and behaviour of current farmers can ensure sustainability of agriculture in the long term. Soil degradation, erosion, water pollution, overuse of chemical products, waste of natural resources, destruction of natural habitats, and resistance to insecticides and pesticides are some of the concerns expressed by environmentalists, ecologists, land managers, political leaders and farmers. There is a great concern about the destructive effects of some agricultural practices focusing on environment, natural resources and sustainable agricultural systems in the long term (Sadati, 2010, cited in Scare et al., 2015).

Summary

This chapter presented the findings on the state of maize production sustainability in the study area. The main focus of the chapter was to empirically establish farm- and farmer-specific backgrounds of the Maize farming households, constraints to maize production enterprises and livelihood diversifications of the farming households. It also brought to fore attitudes of farmers towards sustainable agriculture and their sustainable production practices in the maize enterprises. Garett ranking technique was conducted in ranking the relative importance of the production and postharvest constraints in Maize farming enterprises. The interval standard deviation from mean approach was also conducted in classifying the maize farmers' attitudes toward sustainable agriculture while three different correlation methods: Point Biserial, Spearman's rho and Pearson's Product Moment were performed to examine the degree of association between farmers' farmers attitudes towards sustainable agriculture and farm- and farmer-specific variables. To establish the determinants of attitudes, a multiple regression was conducted. Other analysis conducted in fulfilling the objectives of this chapter included ANOVA and Friedman rank tests show differences between geographical areas and production sustainability respectively.

CHAPTER FIVE

CONTRIBUTION OF MAIZE PRODUCTION TO FOOD SECURITY

Introduction

Agriculture is an important sector for many developing countries, both to drive economic development but also to support poverty reduction and boost food and nutrition security (Department for International Development, 2015). The 2030 Agenda for Sustainable Development and the UN Decade of Action on Nutrition 2016–2025 call on all countries and stakeholders to act together to end hunger and prevent all forms of malnutrition by 2030 (FAO, IFAD, UNICEF, WFP & WHO, 2017). Agricultural production holds a central role in food security in Ghana as it constitutes the main source of livelihoods and provides employment for 60 percent of the population (WFP, 2016).

This chapter of the study presents the findings in relation to the second objective of evaluating the contribution of the maize production to food security. The results of the three domain of the CARI console used for measuring food security indicators are presented. The prevalence of food security is also presented using the food security index (FSI). Each household was assigned to a FSI group based on an averaging process using a 4-point scale scores attained for each indicator. Specifically, each household's FSI classification was based on an average of their current status score and their coping capacity score. The latter is formed from averages of the food expenditure share score and the asset depletion score (WFP, 2015). Chapter three (methodology) provided more detailed description of the processes used to arrive at the results.

Table 39: Classification of respondent households based on food consumption score

Classifications	Geographical zones			Pooled
	Northern	Middle	Southern	
Acceptable (1)	42.4	47.1	33.2	40.9
Borderline (3)	47.8	49.6	63.1	53.5
Poor (4)	9.8	3.3	3.7	5.6
Total	100.0	100.0	100.0	100.0
	ANOVA – Mean separation			
Mean	2.249^{ab}	2.090^{a}	2.373^{b}	2.237
St.Dev.	1.112	1.046	0.988	1.055

Source: Field survey, Akaba (2018)

Scale: 1 = Food secure 3: Moderately food insecure 4: Severely food insecure

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

The results in Table 39 show that, in the Southern zone, about a third of the households were having acceptable level of food consumption score, 63.1 percent of them were on the borderline while 3.7 percent are having poor food consumption scores. For those farming households from the northern part of the region, more than 2 out of 5 had acceptable levels of FCS, about 48 percent and almost 10 percent of them were on the borderline and poor respectively. In the Middle zone, 47.1 percent of the households were classified as having acceptable level of FCS, about half of them are on the borderline and only 3.3 percent were having poor food consumption score. On the whole, food consumption score in the Volta Region maize-farming households indicates that majority of them (53.5%) were moderately food insecure, about 6 percent were severely food insecure and only about 2 out of every 5 households can be categorised as food secure.

The large proportion of the farming households falling into the borderline category does not augur well for sustaining food security situation in the region because any little shock could plunge these households into a serious food insecurity situation. The general findings show the proportion of those from the Middle zone who were food secure or having acceptable level of food consumption score are relative higher than that of the Northern zone which was also higher than those from the south.

Table 40: Classification of respondent households based on food expenditure share

Classification	Geographical zones			Pooled
	Northern	Middle	Southern	
< 50% (1)	25.3	35.2	20.5	27.0
50 - 64% (2)	35.1	40.2	45.1	40.1
65 - 74% (3)	31.0	23.8	32.0	28.9
> 74% (4)	8.6	0.8	2.5	4.0
Total	100.0	100.0	100.0	100.0
	ANOVA – Mean separation			
Mean	2.229[b]	1.902[a]	2.164[b]	2.098
St.Dev.	0.926	0.785	0.774	0.842

Source: Field survey, Akaba (2018)

Scale: 1 = Food secure 2: Marginally food secure

3: Moderately food insecure 4: Severely food insecure

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

However, in terms of those who were severely food insecure, the highest proportion was from the northern part followed by the Southern zone and the least was Middle zone. This was also evident in the analysis of variance (ANOVA) where those from the Middle zone tend have a statistically significant level of food security than those from the Southern zone and Northern zone. Again, using the food consumption score, the level of food security in the Northern zone was not significantly different from those from the Southern zone. The various standard deviations indicate slight variations in the classification of the food security categories when using the food consumption score.

The results of food expenditure share (Table 40), which measures the economic vulnerability of the Maize farming households, reveal that a quarter of those from the Northern zone spent less than 50 percent of their income on food, more than a third (35.1%) spent from 50 to 64 percent of their income on food, less than a third (31.0%) spent 65 to 74 percent while 8.6 percent of them spend three quarters or more of their income on food for the households. For those households from the Middle zone, 35.2 percent spent less than half of their income on food, 2 out of every 5 households spent 50 to 64 percent of their income on food, less than a quarter spent 65 to 74 percent on food while less than 1 percent spent 75 percent or more of their income on food. For the Southern zone, only around 1 out of every 5 farmer spent less than half of their income, with 45.1 percent spending 50 to 64 and less than one-third spending 65 to 74 percent while 2.5 percent spent more than 74 percent of their income on food.

The aggregate data from the region indicate that more than a quarter (27.0%) spent less than half of their income on food, 2 out of every 5 household spent 50 to 64 of their income on food, less than a third spent 65 to 74 percent of their income on food and only 4 percent of them spent three-quarters or more of their income on food for their households. These findings support that of Dethier and Effenberger (2012) that about three-quarters on incomes of farming households are spent on food. The results indicate that those farming households from the Middle zone are statistically significant food secure more than those from both the north and the southern part of the region. However, there was no significant difference in the level of food security level between the north and south maize-farming households from the Volta Region.

Table 41: Classification of respondent households based on livelihood-based coping strategy

Classification	Geographical zones			Pooled
	North	Middle	South	
Normal (1)	35.9	45.5	24.2	35.2
Stress (2)	33.9	32.0	32.8	32.9
Crisis (3)	26.9	22.1	38.5	29.2
Emergency (4)	3.3	0.4	4.5	2.7
Total	100.0	100.0	100.0	100.0
	ANOVA – Mean separation			
Mean	1.976^{b}	1.775^{a}	2.234^{c}	1.995
St.Dev.	0.873	0.803	0.869	0.868

Source: Field survey, Akaba (2018)

Scale: 1 = Food secure 2 = Marginally food secure

3 = Moderately food insecure 4 = Severely food insecure

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

Table 41 presents classifications of households into food security categories using the LCS. The findings reveal that more than a third (35.9%) percent of the maize-farming households from the Northern zone were using normal livelihood-based coping strategies to maintain their food security conditions. Those who fall into this same category in the Middle zone were about 10 percent more than those from the northern. However, less than a quarter of the maize-farming households from the Southern zone were using normal coping strategies. About a one-third each of the maize-farming households from the three geographical zones in the region were using stress coping strategies. The highest proportion of those farming households who were using crisis strategies were found in the Southern zone (38.5%) followed by those from the Northern zone, which is a little more than a quarter (26.0%). Only about 22 percent of those in the Middle zone were adopting crisis coping strategies. A similar trend was found among the proportion of the farmers who were using emergency strategies where Southern zone had the highest followed by Northern and the least being the Middle zone (4.5%, 3.3% and 0.4% respectively).

Considering the aggregates from the region, the results reveal that less than one-third of the respondents were either using more crisis or emergency livelihood-based coping strategies while about a third (32.9%) adopted stressed strategies and more than a third (35.2%) were not using any kind of coping strategies that rebound the households into negative consequences. Using the LCS as asset depletion indicator, the mean food security level in the region could be described as generally marginal. Among the geographical zones, there was statistically significant difference among the three groups where Middle zone was more significantly food secure than the Northern zone while the Southern zone was the least food secure.

Table 42: Prevalence of food insecurity among maize-farming households

Domain		Indicator	Categories			
			Food secure (1)	Marginally food secure (2)	Moderately food insecure (3)	Severely food insecure (4)
Current status	Food consumption	Food consumption score	*(Acceptable)* 40.9		*(Borderline)* 53.5	*(Poor)* 5.6
Coping capacity	Economic vulnerability	Food expenditure share	*(Share < 50%)* 27.0	*(50% - 64%)* 40.1	*(65% - 74%)* 28.9	*(> 74%)* 4.0
	Asset depletion	Livelihood-based coping strategy	*(Normal)* 35.2	*(Stress)* 32.9	*(Crisis)* 29.2	*(Emergency)* 2.7
Food security index			**24.1**	**22.1**	**49.7**	**4.1**
Food security status			**Food secure (46.2%)**		**Food insecure (53.8%)**	

Source: Field survey, Akaba (2018)

Each household was assigned to a FSI based on an averaging process using the 4-point scale scores that household attained for each of the three indicators used to classify the households into the food security levels. Specifically, each household's FSI classification was based on a simple average of their current status score and their coping capacity score. The coping capacity score was formed from averaging the food expenditure share score and the asset depletion score. The final row of the console presents the population's overall food security outcome; this is described as the food security index. This is based on an algorithm which combines, at the household level, the results for each of the reported food security indicators (WFP, 2015).

The food security index indicates that less than a quarter of the respondent households were food secure and around 22 percent were marginally food secure. On the other hand, about half of the respondents (49.7%) were moderately food insecure while only about 4 percent were severely food insecure. As reported by FAO, IFAD, UNICEF, WFP and WHO (2017), food security has deteriorated as economic slowdowns challenge access to food for the poor. Using the food insecurity experience scale (FIES), FAO et al. (2017) estimated the prevalence of severely food insecure among the Ghanaian population for 2014 to 2016 to be 25 percent. In the same report, it was indicated that the three-year estimates for the number of people living in households where at least one adult has been found to be severely food insecure is 6.2 million. In a similar study by De Cock et al. (2013), also found majority of the households (53.0%) to be food insecure.

Those in the food secure group were able to meet essential food and non-food needs without engaging in atypical coping strategies. Those who were marginally food secure have minimally adequate food consumption without engaging in irreversible coping strategies; unable to afford some essential non-food expenditures. The moderately food insecure group had significant food consumption gaps, or were marginally able to meet minimum food needs only with irreversible coping strategies. The severely food insecure had extreme food consumption gaps, or extreme loss of livelihood assets which will lead to food consumption gaps, or worsen (WFP, 2015). Thus as a result of the inability of this category of maize-farming households to meet the food security needs they employed irreparable coping strategies which redound in worsening the food insecurity situations of the households.

The food security index (FSI) represents the final output of the CARI console, which combines the suites of the food security indicators for the three geographical zones of the Volta Region. These results presented in Figure 4 reveal the overall food security status of the maize-farming households.

Table 43: Geographical presentation of the food security index

Levels	Geographical zones			Total
	North	Middle	South	
Food secure (1)	19.6	36.9	16.0	24.1
Marginally food secure (2)	29.0	14.8	22.5	22.1
Moderately food insecure (3)	43.3	45.9	59.8	49.7
Severely food insecure (4)	8.2	2.5	1.6	4.1
Total	100.0	100.0	100.0	100.0
ANOVA – Mean separation				
Mean	2.400^{b}	2.139^{a}	2.471^{b}	2.337
St.Dev.	0.893	0.954	0.777	0.888

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

The results reveal that only 16.0 percent of the maize-farming households in the Southern zone fell into the category of food secure, about 2 out of 10 maize-farming households in the Northern zone were food secure while 36.9 percent in the Middle zone were in this food secure category. For marginally food secure category, less than 30 percent of the respondent households from the Northern zone, about 15 percent from the Middle zone and 22.5 percent from the Southern zone were in this category. The various proportions of the households from the North, Middle and South of Volta who were moderately food insecure were 43.3 percent, 45.9 percent and 58.9 percent respectively. As posited by Shiferaw, et al. (2011), when complemented with market risks associated with poorly integrated domestic and regional markets, small-scale maize producers often face significant challenges in smoothing consumption and income over time. Better varieties for stress tolerance and investment in water management and value chain development will help mitigate these inherent risks.

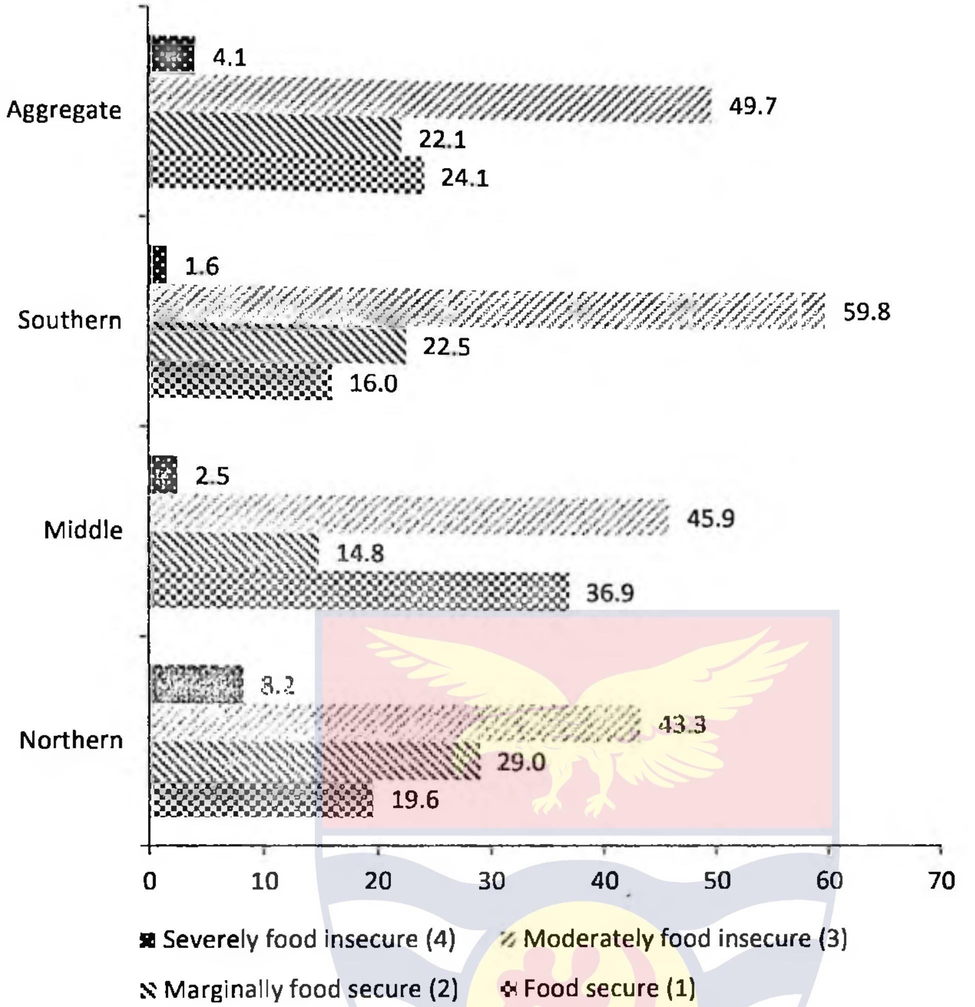

Figure 4: Prevalence of food insecurity among maize-farming households across Volta Region

Source: Field survey, Akaba (2018)

The severely food insecure group distribution was 8.2 percent, 2.5 percent and 1.6 percent respectively in the Northern, Middle and Southern part of the region. Overall, less than a quarter (24.1%) of the households were food secure, 22.1 percent of them were marginally food secure, about half (49.7%) were moderately food insecure while 4.1 percent were severely food insecure. The north, middle and south trichotomy contributed to the inequalities among the Geographical zones with respect to their level of food security. Cooke, Hague, and McKay, (2016) also reported national income inequality between north and south in 2013 to be 10 percent. Volta Region was one of the four regions in the country that saw poverty depth to be rising since 2006, indicating that not enough efforts are being made to improve the lives and welfare of the poor in the regions. Their report further indicated that on average, the poor in those regions, including Volta, are now living deeper in poverty than in 2006.

These findings of from the three geographical locations of the Volta Region is in total variation with the findings from the Comprehensive Food Security and Vulnerability Assessment (CFSVA) by the World Food Programme in 2009 that only 3 percent of the people in the Volta Region are food insecure and about 7 percent of them were vulnerable to become food insecure. At the national level, it was reported that 5 percent of the population is food insecure and about 2 million more are vulnerable to food insecurity (Biederlack & Rivers, 2009). One should have expected an improvement in the findings, however, the situation in the study area seem to be worsened, even more than national figures. A tangible reason could be attributed to the methodology and the kind of variables included in the measurement of food security levels among the households. It could also be that things were getting worse rather than what is thought to be an improvement. This finding corroborates the reports of FAO, IFAD, UNICEF, WFP and WHO, (2017) that after a prolonged decline, this recent increase in food insecurity could signal a reversal of trends. The food security situation has worsened in particular in parts of sub-Saharan Africa, South-Eastern Asia and Western Asia, and deteriorations have been observed most notably in situations of conflict and conflict combined with droughts or floods.

On the other hand, a study by Manu et al. (2013) in the south eastern part of the region using IRT model of classifying households by means of the 18-items revealed that, 26.6 percent of the respondents were food secure, 33.6 percent of them were food insecure without hunger while 39.8 percent of them were food insecure with hunger. Comparing this result to the Southern zone alone, it could be stated that though the number of food secure households has increased (38.5%), those with food insecure (moderate and severe) have also increase by about 9 percent margin. Thus though those in the category of food insecure has reduced, most of those who moved out of this category have a rather worsened conditions than previously. This could be due to crop failures due to recent shocks such as severe droughts, erratic rainfall, and pests attacks including variegated grasshopper and fall army worm outbreaks in this part of the region. These situations destroyed most people's farms leading to low yield and shortage of food in the area.

A study by WFP (2016) on food security situation in Northern Ghana, Brong Ahafo and Volta Regions indicate that 15 percent were moderately food insecure while less than 1 percent of them are severely food insecure. They found 24.8 percent of respondents in the Nkwanta North District to be food insecure (WFP, 2016). It should be noted that the food security assessment in 2016 was conducted in February during a period households would generally be expected to have good stocks of food. Considering the level of household food insecurity at the time of the assessment in 2016, the prevalence could be much higher in this current study. as indicated in their report, even in districts where the prevalence of food insecure was low, there was greater risk of many more households becoming food insecure during the lean season (WFP, 2016). For instance, WFP stressed that more than 60 percent of households are marginally food insecure in Krachi East District and many of those households could move into moderate and severe levels of food insecurity due to shocks and changes in their access to food during the lean season. The WFP findings also revealed that most of those who were in the food insecurity group are food crop farmers whose livelihood is characterized by the lowest annual per capita income, falling below the national poverty threshold of GHc1.47 per capita per day. It further indicated that almost three-quarter of them (72%) cultivate land less than two hectares in size and almost all are entirely reliant on rainwater for cultivation (98%).

Nearly half (48%) of the households have family heads without any educational background (Biederlack & Rivers, 2009).

A Friedman test was conducted to assess if there were differences among the mean ranks of the food security indicators used for the estimates among the maize-farming households in the Volta Region of Ghana. The results are presented in Table 44.

Table 44: Friedman tests for the domains of food security indicators used for classification of maize-farming households

Friedman Test Statistics for the mean ranks	FCS	FES	LCS
Means	2.237	2.098	1.995
St.Dev.	1.055	0.842	0.868
Mean rank	2.14	1.97	1.89
Total observation		733	
Chi-Square		51.456	
Degree of freedom		2	
Asymptotic Significance		.000	

Wilcoxon Signed Ranks Test Statistics			
	FES - FCS	LCS - FCS	LCS - FES
Z[a]	-4.061	-6.801	-3.521
Asymp. Sig. (2-tailed)	.000	.000	.000
a. Based on positive ranks			

Source: Field survey, Akaba (2018)

The chi-square, χ^2 (2, n= 733) = 51.456, p = .000 indicates significant differences among the mean ranks of food consumption score (FCS), food expenditure share (FES) and the livelihood-based coping strategies (LCS), which were the main indicators used to measure food security of the households. Three orthogonal contrasts were therefore performed using Wilcoxon Signed Ranks Test with the Bonferroni correction (comparison-wise alpha = .017) (Leech, et al., 2005). The contrast between FCS and FES (Z = 4.061, p = .000), FCS and LCS (Z = 6.801, p = .010), and FES and LCS (Z = 3.521, p = .000) were all found to be significant. In all cases, the significant contrasts indicate that the maize-farming households were most food secure when using livelihood-based coping strategies followed by the food expenditure share and then food consumption score.

The importance of gender in assessing food security cannot be overemphasised. As men and women often have different roles and responsibilities in securing adequate food at the household level. Extreme cases of food insecurity could tend to change gender roles and social norms. Prolonged food insecurity could render individuals in the households to be more vulnerable to risk of ill-health or life-long disabilities. Rural women often have less access to resources and income, which makes them more vulnerable and hence more likely to resort to riskier coping strategies. These strategies may affect their health, which in turn is detrimental to the food security of the entire household as food production and the ability to prepare food decreases with illness (FAO, IFAD, UNICEF, WFP & WHO, 2017; Brinkman, Attree, & Hezir, 2013). This study therefore delved into the segregation of the food security levels according to the sex of respondent in the maize-farming households. Table 45 presents the independent sample t-test between the female and male respondents in the households selected for the study.

The results indicated that males tend to be more food secure than their female counterparts in all the domains of the CARI console. However, only the FCS had a significant difference; the FES and LCS did not show any statistically significant difference between the males and females. On the whole, there was statistically significant difference between males and females in the FSI.

Table 45: Food security levels by sex of respondents

	Sex	N	Mean	Std. Dev.	Std. Error Mean	Mean Diff.	Std. Error Diff.	t-value	Sig.
Food consumption score	Female	177	2.384	1.0387	.078	0.194	.090	2.150	.032
	Male	556	2.191	1.0567	.045				
Food expenditure share (Economic vulnerability)	Female	177	2.170	.84246	.063	0.094	.073	1.294	.196
	Male	556	2.076	.84131	.036				
Livelihood-based coping strategy	Female	177	2.073	.87271	.066	0.104	.075	1.389	0.165
	Male	556	1.969	.86626	.037				
Food insecurity index	Female	177	2.458	.83914	.063	0.159	.074	2.157	.032
	Male	556	2.299	.90089	.038				

Source: Field survey, Akaba (2018)

Food insecurity among female-headed household is reported to be linked to limited access to land and agricultural inputs as control over essential natural resources rest with their male counterparts. By virtue of the unequal access to resources (such as land, credit and extension services), their ability to produce enough and gain adequate access to food is constrained (WFP, 2016). Although they constitute less than a quarter (24.1%) of the households in the assessment, a large proportion of female-headed households (70.1% versus 63.1% of male-headed households) were engaged in the use of atypical or distress livelihood-based coping strategies due to lack of food or money to buy food. As asserted by WFP (2016), a higher proportion of female-headed households are food insecure as compared to their male due to limited access to inputs and lack of financial resources to expand production. Moffitt and Ribar (2016) also reported that there is a marked difference in gender patterns of food insecurity.

Table 46: Distribution of food security level by marital status of respondents

Food security indicators	Marital status	N	Mean	Std. Dev.	Std. Error Mean	Mean Diff.	Std. Error Diff.	t-value	Sig.
Food consumption score	Unmarried	137	2.402	1.053	.090	0.200	.100	2.005	.045
	Married	587	2.201	1.053	.043				
Food expenditure share	Unmarried	137	2.161	.825	.070	.079	.080	.984	.325
	Married	587	2.081	.849	.035				
Livelihood-based coping strategy	Unmarried	137	2.051	.877	.075	.070	.083	.845	.398
	Married	587	1.981	.869	.036				
Food insecurity index	Unmarried	137	2.467	.883	.075	.162	.084	1.923	.055
	Married	587	2.305	.890	.037				

Source: Field survey, Akaba (2018)

Revelations similar to the distribution of food security levels among females and males could be seen in the marital status, where those who are either married or cohabiting tend to be more food secure than those who are not married (Table 46). In all the indicators, the unmarried were more food insecure than those who were married. However, apart from the current status domain of the food security indicators, the rest are not significantly different. As indicated by Moffitt and Ribar (2016) having a spouse to help with household production in other aspects may free up time for the food preparation and to ensure that all members of the household obtain the needed food consumption level.

Food-Based Coping Strategies among Maize-farming Households

People typically first engage in reversible coping strategies with short-term effects, such as making modest dietary adjustments and skipping meals. However, as coping options are exhausted or disappeared and food insecurity worsens, households are more likely to employ more extreme and damaging strategies that are less reversible and therefore represent a more severe form of coping, such as distress selling of livestock or productive assets such as farm tools (FAO, IFAD, UNICEF, WFP & WHO, 2017). Severe and/or persistent food insecurity can ultimately lead to the collapse of coping mechanisms, prompting migration, destitution and, in extreme cases, death and starvation. Coping mechanisms and loss of livelihoods can in turn undermine local and national economies. Children's roles in the household could also be severely affected, as many are at risk of being pulled into child labour during times of worst forms of food insecurity. Based on these assertions, the study delved into the coping strategies that the maize-farming households employ to avert food insecurity (Figure 5).

Some 54.2 percent of households employed consumption-based coping strategies because of the lack of food or money to buy food during the 12 months preceding the assessment. The apparent lack of food or money to purchase is partly the result of very low staple stocks from the cropping seasons.

The most commonly employed coping strategy was reliance on less preferred or less expensive foods followed by a changing diets and reduction in amount of food intake; skipping meals or reduction in the number of meals consumed in a day was the least used consumption-based coping strategy. A similar study by WFP (2016) also reported reliance on less preferred or less expensive foods as the most common consumption-based coping strategy among sampled households.

This implies that households in the moderate and severe food insecurity categories are using more frequent and more severe coping strategies relative to those within food secure and marginally food secure categories, and are therefore more vulnerable to food insecurity than their counterparts in other districts. The use of consumption-based coping strategies varies significantly among the food security groups. Some 89.2 percent of severely food insecure households used coping strategies, compared to 94.0 percent moderately food secure households and 77.8

percent for marginally food secure. This finding partially concurs with WFP (2016) assessment, where they found 86 percent of severely food insecure, 65 percent of moderately food secure and 62 percent of marginally food secure households to use coping strategies.

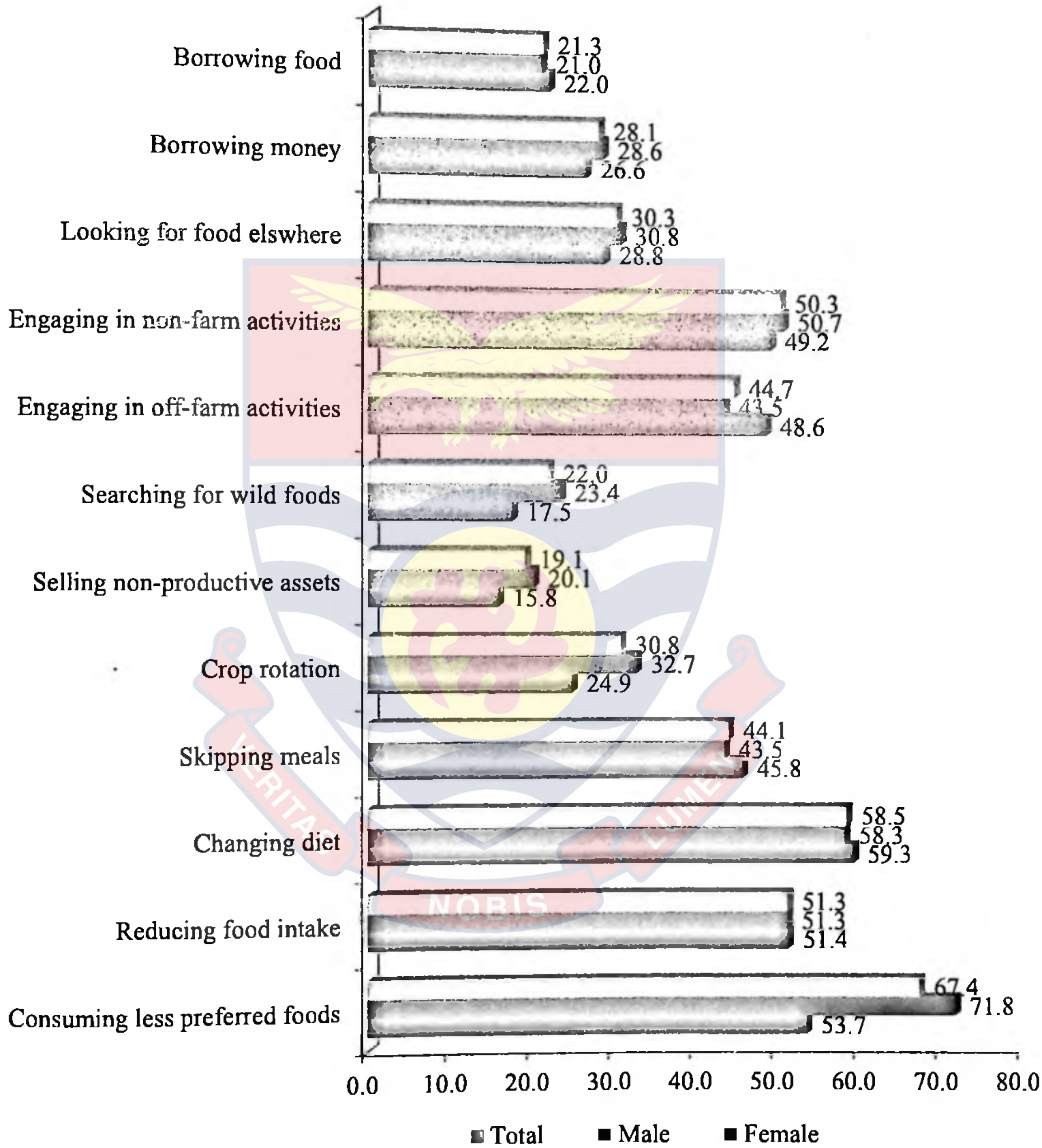

Figure 5: Coping strategies of females and males to avert food insecurity

Source: Field survey, Akaba (2018)

However, shifting gender roles as a result of food insecurity can have beneficial effects on household welfare. Where women gain more control of resources, household food consumption tends to increase and child nutrition improve. Their economic empowerment may further give them greater voice in household and community decision-making (FAO, IFAD, UNICEF, WFP & WHO, 2017).

Maize-farming households in the Volta Region employ different types of coping strategies either to avert food insecurity to reduce its effect on the households. Both food secure and food insecure households tried to use several means of dealing with food insecurity situations. As reveal from the findings in Table 47, majority of the respondents deal with food insecurity conditions by changing their diet (58.5%). Similarly, majority of them also consume less preferred food types (54.4%), reduce food intake (51.3%), or engage in non-farm activities (50.3%) to deal with food insecurity situations.

Table 47: Coping strategies used by households within food security categories

Coping strategies	Food secure (f = 347)	Marginally food secure (f = 126)	Moderately food insecure (f = 149)	Severely food insecure (f = 111)	Pooled (n = 733)
Consuming less preferred foods	43.8	42.9	73.8	74.8	54.4
Reducing food intake	28.5	54.8	81.9	77.5	51.3
Changing diet	56.2	47.6	73.8	57.7	58.5
Skipping meals	21.3	42.1	72.5	79.3	44.1
Crop rotation	28.8	24.6	34.9	38.7	30.8
Selling non-productive assets	19.6	14.3	18.8	23.4	19.1
Searching for wild foods	22.2	17.5	20.8	27.9	22.0
Engaging in off-farm activities	43.5	37.3	44.3	57.7	44.7
Engaging in non-farm activities	43.2	46.0	60.4	64.0	50.3
Looking for food elsewhere	27.7	23.8	26.8	49.5	30.2
Borrowing money	19.3	19.8	38.9	50.5	28.1
Borrowing food	17.0	21.4	29.5	23.4	21.3

Source: Field survey, Akaba (2018)

Some of the coping strategies that are less employed by the respondents' households include the sale of non-productive assets (19.1%), borrowing food (21.3%) or money for food (28.1%), searching for wild foods (22.0%) and looking for work elsewhere (30.2%). These types of coping strategies are mostly used in severe cases of food insecurity. Thus, majority of the households who use these extreme coping strategies are found within the severely or moderately food insecure categories. As indicated in Table 47, those households who were classified as food secured tend to use less number of coping strategies than those who have some level of food insecurity. The results also reveal that, households who found in a less food security situations tend to use more coping strategies that those households who are more food secure. Thus the more food insecure a household is, the more they use different types of coping strategies to avert or alleviate their food insecurity conditions.

Farm- and Farmer-Specific Determinants of Food Security Status

A binary logistic regression analysis was ran to determine the independent variables that predict the food security status among the maize-farming households. This was done by collapsing the four scale food security levels into two groups where marginally food secure and food secure levels were put into food secure status while the moderately food insecure and severely food insecure were put into food insecure status (Shiferaw, Kilmer, & Gladwin, 2003; Gujarati, 2004; Bogale & Shimeles, 2009; Tagel & Van der Veen, 2010; Manu, Akuamoah-Boateng, & Akaba, 2013; Mequanent, Birara, & Tesfalem, 2014; Hailu, Alemu, & Zaid, 2018).

In all, twenty-four (24) independent variables were entered for the prediction in the regressions with the food security status being the dependent variables. Eleven (11) of these predictor variables were used to explain food security level, since they were deemed to meet the criteria for logistic estimation. Table 48 summarised the results of the regressions computed for the dependent and independent variables. The results revealed that the model explained between 33.0 percent (Cox and Snell R-square) and 44.3 percent (Nagelkerke Rsquare) of variance in the food security status of the maize-farming households.

Table 48: Binary logistic regression analysis for the determinants level of food security among maize-farming households

	B	S.E.	Wald	df	Sig.	Exp(B)
Sex (Male)	.764	.507	2.275	1	.131	2.147
Years of education	.081	.041	3.897	1	.048	1.084
Household size	.029	.060	.230	1	.631	1.029
Maize farm size	.092	.041	4.967	1	.026	1.096
Use of improved seeds	.285	.518	.302	1	.582	1.330
Paid for land	-1.658	.529	9.822	1	.002	.190
Farming as main occupation	-2.280	1.163	3.841	1	.050	.102
Row planting	.646	.212	9.304	1	.002	1.909
Access to extension services	.502	.219	5.247	1	.022	1.652
Land productivity	.399	.108	13.671	1	.000	1.491
Number of family labour	.097	.102	.898	1	.343	1.101
Constant	-.926	1.508	.377	1	.539	.396

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	141.963	.330	.443

Hosmer and Lemeshow Test of goodness of fit

Chi-square	df	Sig.
9.467	8	.304

Omnibus Tests of Model Coefficients (Likelihood Ratio test)

		Chi-square	df	Sig.
Step 1	Step	32.762	11	.001
	Block	32.762	11	.001
	Model	32.762	11	.001

Source: Field survey, Akaba (2018)

The Wald chi-squared statistics, as revealed from Table 48, are not statistically significant for sex of respondent, household size, use of improved seeds, and number of family labour used (i.e., p-values of 0.131, 0.631, .582 and 0.343 respectively), whereas those of the rest seven explanatory variables were significant at the $\alpha = 0.05$. Thus, given that the four predictors remain in the model, removing any of the rest seven (i.e. years in education, maize farm sizes, paying for land for maize production, farming as maize occupation, row planting, access to extension services and land productivity) as a predictor would result in significantly poorer predictive efficiency, although removing any of the other four predictors (sex of respondent, household size, use of improved seeds, and number of family labour used) would not have a significant impact. The individual values of the Standard Error of Estimate (S.E.) also show a relatively high accuracy of prediction in the regression model. It can therefore be deduced that any change (increase or decrease) in any of the seven significant independent variables can go a long way to impact either positively or negative on the food security status of the Maize farming households.

From Hosmer and Lemeshow test, the data provides a good fit to the model estimates, as the Hosmer statistics gives a non-significant Chi- square value of 9.467 at 5% level of significance. The -2log Likelihood = 32.762 which is significance at 0.05 level of significance implies that at least one of the parameters is not equal to Zero and the model is well fitted. Thus, the full model is significant as shown by -2LogLikelihood statistic.

Ogunfiditimi and Oguntade (2014) stated that a sample has a decrease probability of having food security if the estimated odds ratio of its variable(s) is less than one and if the odds ratio is greater than one then there will be an increased probability of food security prevalence. Using the odd ratios, the analysis showed that households that had males to be their household heads were more than 2 times likely to be food secured compared with households with female respondents. Indirectly, most of the respondents were household heads. This reveals the implication that those households who are headed by females tend to be less food secure than their male counterparts.

Regression equation for food security status

Using the eleven predictor variables which were used to explain food security status, the logistic regression equation for the log-odds in favour of food security was estimated as

$$Log_e\left[\frac{FS}{1-FS}\right] = -0.926 + 0.764Sex + 0.081Edu + 0.029HHSiz + 0.092FmSiz + .285ImpSeed - 1.658LndPay - 2.280Occup + 0.646RowPlt + 0.502ExtServ + 0.399Pdty + 0.097FamLab.$$

The results also reveal that those who spent more years in formal education tend to be more food secured than their counter parts. In other words, the log odds of having a one-year increase in the education could lead to more than 8 percent improvement in food security. This confirms the findings of separate studies by Kidane et al. (2005), De Cock, et al. (2013), Chinnakali, et al. (2014) and Abdullah, et al. (2017), that human capital development through education is important contributer to household food security.

Similarly, a one acre increase in land size for maize production would lead to more than 9 percent increase in food security, all other variables held constant. Bogale (2012) also found out in his study that cultivated land size is a significant determinant of household food security. However, those maize farmers who pay for their land for production, either through rent, leasehold or share cropping are 5 times likely to be more food insecure that those who either use their own land or family lands for maize production. Thus, all things being equal, use of own or family land without paying tend to improve food security status more than paying for land. Again, those respondents households who were mainly into farming as their source of livelihood tend to be about 10 times more likely to be food insecure than those farming households who have other occupations such as teaching, civil service, artisanal, security services and trading.

Further, those who adopt the technology of row planting tend were 90 percent more food secure than those who planted using other means. As indicated by Armah et al. (2011), the lack of technological change impedes the growth of agriculture and adaptation is necessary for achieving food security. Access to extension services also showed about 65 percent likely of increasing food security. Thus those who were able to have access to extension service from both public and private service providers are likely to be more food secure than those who could not access extension services. This supports the findings of Bagole (2012) and Gill and Khan (2010) that access to extension services help improve food security levels of households. The amount of maize yield derived from an acre of land for the households also reveals a likely increase in the food security levels by 50 percent. Thus, a unit increase in productivity tends to improve maize-farming households food security status.

Summary

This chapter of the study presented the empirical findings of the contributions of maize production enterprises to food security of households in the study area. The chapter focused on the use of the CARI Console to establish prevalence of food insecurity among the maize-farming households and farm- and farmer-specific determinants of food security in the area. The measure of significant differences in the food security levels of farming households from the three geographical areas in the region was also established in this chapter. A Friedman rank test was also performed among the food security indicators to show differences in their respective measurements.

CHAPTER SIX

CLIMATE CHANGE RESPONSE STRATEGIES

Introduction

Subsistence rain-fed agriculture underpins the majority of rural livelihoods in sub-Saharan Africa (SSA) and supports the livelihoods of over 60% of the population (Staatz et al., 2007; IFAD, 2010; Livingston et al., 2011 cited in Mafongoya, & Ajayi, 2017). As reported by IPCC (2007), most developing countries will become more vulnerable to crop failures and reduction in yields. To avert the negative impacts on the sustainability of the agricultural sector, there is the need to underscore the deleterious effects of climate change and variability and how it could be addressed. This chapter therefore delves into maize farmers' perception of climate change and its effects on maize production enterprises. The chapter also evaluates the adaptive capacity and level of resilience of these farmers by assessing the coping strategies that they have adopted to prevent the negative effects of the climate change and variability.

Climate Change and Variability

Percentage distribution of maize farmers who affirmed the occurrence of climate change and variability is presented in Table 49. Most of the farmers affirmed to the fact that they have noticed more climate change and variability or unusual climatic conditions across the Volta Region (86.1% and 90.6% respectively for temperature and precipitation). This finding supports a study by Mase, Gramig and Prokopy (2017) that majority of farmers agree or strongly agree that they have noticed more variable or unusual weather on their farm. Within the various geographical zones, similar proportions of farmers from the North, Middle and South of the region asserted that there have been experiences of extreme temperature in their localities. On the other hand, the proportion of farmers who said there have been changes in precipitation were higher in the Middle zone (95.9%) compared to those from the South (88.9%) and the North (87.0%). This is an indication that most maize farmers are really feeling the occurrences and effects of climate change and variability. IPCC (2014) reported that local awareness and vulnerabilities of climate change and variability are increasing among global communities. This gives credence to the fact that climate change is having deleterious effects on production and livelihood outcomes including food security. This has also been confirmed by FAO (2017b) that recent drought has had devastating impacts on agriculture and food security. Stanturf et al. (2011) also reported delays in the onset of the rainy season, heavier rains late in the rainy season, and increased flooding, causing crop damage.

Table 49: Percentage distribution of maize farmers' perception on changes in temperature and precipitation

Statements	Geographical zones			Total
	North	Middle	South	
Change in temperature	84.6	86.5	87.2	86.1
Change in precipitation	87.0	95.9	88.9	90.6
Flood	62.9	69.7	67.2	66.6
Drought	96.3	81.6	84.0	87.3
Wind	68.2	70.9	84.4	74.5
n	245	244	244	733

Source: Field survey, Akaba (2018)

The critical role that local perceptions play in decision-making cannot be overstated. It is common knowledge that uptake tends to be associated with perceptions regarding relevance and importance. Generally, most of the maize farmers indicated their noticing of changes in precipitation and high variability in rainfall patterns. This was across the three geographical zones of the region. The farmers observed that the rains were starting late and they can no longer predict the likely arrival, duration or quantity of rain. This, they indicated, is affecting their farming activities. In some cases, farmers had to plant two to three times before a normal rainfall pattern will be established. In other cases, good rainfall activity was observed at the start of the season, only to be replaced by dry spells mid-season, with devastating consequences for crops including maize. Most farmers also perceived the rain to be highly erratic and poorly distributed over the past years. As per their observations, the amount of rainfall was perceived to have reduced resulting from declining amounts, more erratic, high variability, shift in the onset date and early cessation. The finding of this study is congruent with observed trends of decreasing rainfall and increasing temperatures in the last several decades as reported by Stanturf et al. (2011). These factors combine to make the farmers most vulnerable to adverse effects from climate change.

Temperatures were generally perceived to be increasing annually with the warmer periods beginning earlier than previously. There were also reports of mid-season droughts. Most of the farmers across the region also indicated their experiences of worse conditions of droughts and prolonged dry spells in recent years. They recapitulated that, gone are the years, where high temperatures used to be associated with high likelihood of rainfall, but this it is no longer the case nowadays. There is also evidence to show from Zimbabwe that increased rainfall variability and temperatures have reduced smallholder farmers' adaptive capacity and increasing their vulnerability to climate change (Mugabe et al., 2010).

About three-quarters of the farmers from the region reported notable increases in strong winds associated with destructions of their crops most especially the tree crops including plantain and banana, and grains mainly maize and other crops like cassava. This situation renders them to be more vulnerable to food insecurity. Additionally, increasing strong winds, which often disperse the rain clouds, is altering the rainfall pattern, which compounds the problems of the inability to forecast and plan farming activities that will meet the seasonality of the rain. Major climatic events reported by the farmers including warming temperatures and declining rainfall trends. Exactly a third of the respondents across the region also indicated increases in flood at their farmers and communities.

As posited by other authors, agriculture is a significant contributor to greenhouse gas emissions, and it is also vulnerable to changing weather patterns, diseases and pests expected to result from climate change (IPCC, 2007; Walthall et al., 2012; Mase, Gramig, & Prokopy, 2017). The scientific evidence has shown that climate change is a global challenge facing humans and their socio-economic activities, health, livelihood, and food security (Romieu et al., 2010; Clarke et al., 2012; Amjath-Babu et al., 2016). Rural farmers in Sub-Saharan Africa are likely to be more vulnerable to climate change, particularly because of compounding challenges of poverty, low infrastructural and technological development, and high dependence on rain-fed agriculture (Ericksen et al., 2011; Lipper et al., 2014; Nelson et al., 2014; Adimassu & Kessler, 2016).

Warming of the ocean surface above average was severe in 2015 and 2016 during which this study was conducted. As reported by FAO (2017a), El Niño within these two years is one of the intense and widespread in the past 100 years, and this has impact on crops and livestock production and livelihoods. The agriculture, food security and nutritional status of tens of millions of people in Africa are currently affected by El Niño related droughts and floods. In early July 2016, FAO estimated that more than 60 million people faced food shortages because of El Niño-related droughts. The expected effects of climate change, including higher temperatures, extreme weather events, drought, rising sea levels, disruption of ecosystems and loss of biodiversity, will seriously affect agriculture and rural livelihoods if no action is taken to improve adaptation and mitigation capacity at local, country and regional levels (FAO, 2017).

Climate Change Effects

Agricultural production vulnerability to climate change is one of the greatest challenges facing the sustainability of the global food system. While increasing levels of carbon dioxide in the atmosphere could be seen as a boon to crop production, negative impacts of climate change – such as increasing temperatures and more variable rainfall patterns – are expected to outweigh any benefits for agricultural production (Walthall, et al., 2012; Latorre, Wilmshurst, & von Gunten, 2016; Mase, Gramig, & Prokopy, 2017; Steffen, et al., 2018). The results of how climate change and variability had affected the maize production enterprises in the Volta Region were presented in Table 50.

Most of the farmers have affirmed the fact that changes in temperature and precipitation have negative effects on their yield. Most of them claimed that the reduction in yield could partly be due to their inability to forecast or predict the behaviour of these major climatic factors and adjust their production accordingly. This finding cut across the whole region where an average of about 95 percent and 89 percent of the farmers respectively indicated that the variability in temperature and rainfall led to their inability to achieve optimum yield from their maize production. These claims support Xie et al. (2014) that rainfall which varies drastically across Africa, often limits agricultural production during dry seasons and droughts. This also confirms the assertion by Sarr (2012) that in West Africa, it is expected that rainfall will be more variable and less predictable, which will reduce the length of the growing season. Crop production is reliant on predictable temperatures as well as timing and amount of precipitation, particularly during critical stages of plant development (Walthall et al., 2012; Mase, Gramig, & Prokopy, 2017).

Table 50: Percentage distribution of perceived effects of changes in temperature and precipitation

Perceived effects	Geographical zones						Pooled	
	Temperature			Precipitation				
	NV	MV	SV	NV	MV	SV	Temp.	Precip.
Reduce yield	99.6	95.9	88.5	96.3	82.4	87.7	94.7	88.8
Reduce soil fertility	87.4	73.4	80.2	76.8	54.9	85.2	80.4	72.3
Increase severity of disease/pest incidence	82.1	33.6	86.8	71.5	45.9	76.5	67.5	64.7
Increased weed control	94.3	50.0	88.9	81.7	29.9	84.8	77.8	65.5
Difficulty in postharvest handling	58.9	24.6	77.8	50.8	41.8	86.4	53.8	59.6
Reduce water level for uptake by plants	96.3	81.6	84.0	88.2	87.3	77.0	87.3	84.2
Reduce vegetative cover	68.3	70.9	84.4	56.1	44.3	87.7	74.5	62.6
	ANOVA – Mean separation							
Differences in mean number of effects	*5.825^{b}*	*4.631^{a}*	*5.816^{b}*	*5.449^{n}*	*4.422^{m}*	*5.721^{n}*	*5.424*	*5.198*
Standard deviations	*1.557*	*1.316*	*1.365*	*1.608*	*1.670*	*1.456*	*1.521*	*1.674*

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

More than two-thirds of the respondents reported increased severity of diseases and pests. There were massive reports of invasion of new species of pests and diseases across the region. Notable among these new species that farmers opined to be as a result of extreme climate effect was the fall army worm (FAW), the Spodoptera frugiperda. Previous literature indicates that it was first reported as present in West African, including Ghana in January 2016 (Goergen, Kumar, Sankung, Togola, & Tamò, 2016). Subsequent investigations have revealed the pest is in nearly all of sub-Saharan Africa (SSA). The location(s), date(s), mode, and number of introductions are not known at present but anecdotal observation suggests its present for several years. The generally hospitable agroecological conditions for FAW in SSA suggest that FAW will establish as an endemic, multigenerational pest in Africa (Prasanna, Huesing, Eddy, & Peschke, 2018). Due to its rapid spread and distinctive ability to inflict widespread damage across multiple crops, FAW poses a serious threat to the food and nutrition security and livelihoods. Although the patterns of population persistence, dispersal, and migration in Africa are yet to be determined, conditions in Africa, especially where there is a bimodal rainfall pattern, suggest that the pest can persist throughout much of the year (Prasanna, Huesing, Eddy, & Peschke, 2018).

Ghana faces challenges of making substantial progress in food security because average yields have remained stagnant over the years. With changing climate, substantial increases in crop yields are needed for food security in Ghana (Armah, et al., 2011; Rademacher-Schulz, Schraven, & Mahama, 2014). They warned that crop management might be inadequate for the new climatic conditions. Stutley (2010) indicated that extreme temperature in Ghana was the source of low yields in the crop production and similarly, Mendelsohn et al. (2006) contended that extreme temperatures and prolonged drought periods in Ghana were the major causes of low crop productivity. Chaudhari, Rajkumar, and Shreedhara (2018) indicated that most of the crop failures worldwide are associated with either a lack or excess of rainfall. The changing rainfall pattern has been reported by Bello et al. (2012) to increase the incidence of pest, diseases, drought and flooding; this will eventually increase the possibility of food shortages and price increase, thus wiping out most of the gains made in reducing poverty that will be realized without climate change.

Current indications are that, by 2020, yields from rain-fed agriculture could reduce by up to 50 percent. Agricultural production, including access to food, is projected to be severely compromised in many African countries. This would further adversely affect food security and exacerbate malnutrition (FAO, 2017). They farmers also added that most of the time, the rain becomes intense during the time of harvesting or when they are supposed to undertake postharvest activities like drying of grains. Sometimes, it is very difficult for them to dry their grains due to unpredictability of the raining patterns. This therefore leads to postharvest lost and poor quality products, which reduces the market value of their outputs. As reported by the respondents, majority indicated that both changes in temperature and precipitation have negative effects on their postharvest handling. These respondents from the Southern Volta claimed to have difficulty handling their outputs after harvesting due to changes in temperature (77.8%) and rainfall (86.4%). For those in the middle Volta, only about a quarter and 2 out of every 5 asserted to the fact that changes in temperature and precipitation respectively render postharvest handling difficult. These findings concur with Chaudhari, Rajkumar, and Shreedhara, (2018) that erratic climatic conditions and their variability with time play important role in the crop production and overall yield.

Response Strategies for Attenuation of Climate Change Effects among Maize Farmers

Climate change is fundamentally changing the way agriculture is practised. Drastically different weather patterns, shorter growing seasons, extreme weather, and many other changes pose daunting problems for smallholder farmers around the world, especially in the tropics (Global Citizens, 2016). As Walthall et al., (2012) pointed out, "because agricultural systems are human-dominated ecosystems, the vulnerability of agriculture to climate change is strongly dependent not just on the biophysical effects of climate change but also on the responses taken by humans to moderate those effects" (p. 119). In order to maintain productivity in the face of the climate challenges maize farmers, need to adopt strategies that are effective and sustainable. To better withstand and adapt to the precarious changing climate, these farmers employ series of strategies which have resultant implications for sustainability. According to Armah et al. (2011), adaptation is necessary to ensure food security in the country. The study therefore assessed the kind of strategies adopted by the maize farmers in obviating the deleterious effect of climate change and variability. The results are presented in Table 51.

Plant residue retention as an adaptation strategy has been found to be the most used method. In addition to maintaining soil moisture and cover the soil from the direct impact of the hot sunshine, residue retention often increases grain yields and improves environmental outcomes (Knowler & Bradshaw, 2007; Giller, et al., 2011; Aulakh , et al., 2012; Mupangwa , Twomlow, & Walker, 2012). In his study, Komarek (2013), used crop residues as mulch (in conjunction with no-tillage) and found out that soil water and soil nitrogen content increased, and this translates into higher production.

Table 51: Climate change response strategies adopted by the maize farmers

Response strategies	Geographical zones			Pooled
	North	Middle	South	
Plant residue retention	75.6	83.6	90.1	83.1
Planting in multiple periods per season	80.9	51.2	81.9	71.4
Use of multiple locations per season	80.1	59.4	57.6	65.8
Increasing frequency of cultural practices	67.5	40.2	77.0	61.5
Changing/timing planting dates	53.9	43.9	81.1	59.6
Integrated soil fertility management	50.8	46.1	79.3	58.7
Mixed cropping	25.6	35.2	81.1	47.3
Changing varieties of maize	27.3	15.2	34.0	25.5
Consult experts on production and timing	21.2	14.3	12.3	16.0
Selling of fresh corns	23.6	15.2	5.3	14.5
Planting of economic trees	3.7	18.0	5.3	9.0
Agroforestry	6.5	12.3	5.3	8.0
Use of early maturing seeds	11.8	3.7	5.3	7.0
Planting only certified seeds	9.4	4.1	7.0	6.8
Prompt weeding	67.8	40.2	76.6	61.5
Planting drought tolerant varieties	12.7	4.5	22.5	13.2
Planting disease resistant varieties	6.9	12.7	6.1	8.6
Plant pest tolerant varieties	10.2	21.3	8.6	13.4
Planting weed tolerant varieties	3.3	7.8	11.1	7.4
Use of irrigation	5.7	4.9	1.6	4.1
Regulated herbicides use	39.2	38.9	33.6	37.2
Regulated pesticides use	20.8	18.4	24.2	21.1
Minimum tillage	35.1	31.1	20.9	29.1
Use of fertilizer	60.4	42.2	39.8	.5
Application of manure	11.8	7.8	27.9	15.8
Use of green manure	40.4	39.3	27.5	35.7
Use of mulch	75.5	83.6	90.2	83.1
Use of crop rotation	27.8	18.4	46.3	30.8
Crop diversification	82.9	73.4	66.4	74.2
Mixed cropping	28.6	48.4	80.7	52.5
Biodiversity conservation	49.4	43.9	27.0	40.1
Planting across slopes	79.6	77.0	62.7	73.1
Diversification of enterprises	43.3	58.6	73.8	58.5
Seed priming	26.1	55.3	58.6	46.7
ANOVA mean separation				
Mean number of response strategies adopted	5.38^b	4.42^a	6.23^c	5.34
Standard deviation	1.99	2.09	1.61	2.05

Source: Field survey, Akaba (2018)

Note: Means with same superscript are not significantly different; means with different superscripts are significantly different from each other.

Komarek (2013) indicated that maximum production occurs when all residues are retained though this might not necessarily translate into maximum economic value. High levels of groundcover can also reduce the susceptibility of soil to wind and water erosion. As can be deduced from Table 51, at least three-quarters for the farmers from the Northern zone (75.5%) are using crop residue as mulch to reduce the climatic effect of soil infertility, reduce water levels, difficulty in weed control and eventual reduction in yield. In a similar situation, at least 4 out of every 5 farmers from the middle zone and 9 out of every 10 farmers from the southern zone were using residue retention as a strategy against climate change effects. This is an indication of farmers striving to overcome the negative effects that the extreme weather conditions are posing to them in the region. This practice of retaining plant residue also helps to keep the soil during heavy rains and floods and nix loss of soil fertility through erosion. Plant residue retention is practised mostly as a means of conserving soil moisture. Kergna and Dembélé (2018) argued that incorporating crop residue in the soil is important in enriching the soil and keeping its moisture as long as possible. This should normally be done during dry season. This is also supported by Howden et al. (2007) who reported that wider technologies are used to increase water availability especially in periods of decrease rainfall. They also added that technologies such as crop residue retention are used in managing water to prevent water logging, erosion, and nutrient leaching were rainfall increase.

The timing of phenological occurrences like tasselling are in one way or the other influenced by climatic factors such as light, rainfall and temperature. Given the complexity of flowering physiology and its relation to the environment, not all species, or all reproductive phases respond to temperature in a uniform manner (Battey, 2010). Changes in climate could lead to asynchrony between the maize plants and the weed plant species, which could eventually result in undue competitions that may affect the performance and yield of the maize plants (Sivakumar, Lal, Selvaraju, & Hamdan, 2013). As a strategy to reduce the adverse effect of climate change, some of the farmers in the Volta Region do not plant maize at one time within a season but resorted to planting at different time intervals. This is done to prevent total crop failure as a result of environmental changes. Thus farmers may plant at different time periods within the same season to avert losing all in case there was incidence of droughts, pests or diseases attacks.

Another reason given by most farmers who adopted this type of strategy is their ability to harvest at successive intervals without leaving the maize on the field for too long a time after maturity. This helps prevent postharvest loss and reduces the hassles during postharvest handling. While only a little more than half of the farmers from the middle zone are using this particular strategy, more than 80 percent of the farmers from the northern and southern zone undertook the planting of maize at different time intervals. This could be as a result of the kind of perceived effects experienced by these farmers in different part of the region. For instance in Table 50, most farmers in the northern and southern zone indicated that both extreme temperature and precipitation had damaging consequences of increased pest and disease incidence. They therefore needed strategies such as this to reduce the destructive effect of the pests and diseases which could lead to low yield or even total crop failure.

A similar strategy used by majority of farmers in the region for prevention of deleterious climate change effect is producing maize at different locations or on different plots. The results indicate that more than 80 percent of farmers from the Northern zone (80.1%), almost about 60 percent of the farmers from the middle zone and majority of those from the southern zone (57.6%) planted at different location with the reason of reducing adverse climate change impact. It should be noted that, there could be other reasons including inability to acquire adequate land at a single locations due to land tenure security problems and pressure on land for other purposes like infrastructure developments. However, one of the major reasons given for this practice is that, if there is a climate related disaster such as outbreak of disease or pests, or crop failure due to drought or flood at a particular location, they (farmers) will at least get some of the maize output from other plots/locations to cushion themselves against food insecurity.

Majority of the farmers in the region were also forced to increase the number of times they undertake cultural practices such as weeding, fertilizer application, and pests and diseases control. While only 2 out of every 5 farmers in the middle zone have to increase the frequency of cultural practices, almost double that proportion increased the frequency of cultural practices in the southern zone. From the northern zone, 67.5 percent of the farmers had to increase their cultural practices so that they could avoid the negative impact of extreme climate conditions. Increase in husbandry activities have economic implications where farmers had to expend more time and resources on labour, pesticides and fertilizer to be able to achieve appreciable level of outputs as compared to previously where there was no climate change effect. Sometimes, the indiscriminate use and inappropriate use of these pesticides, could affect the sustainability of the production. As posited by Amekawa (2010). Poor farmers and farm workers are the most affected victims of pesticide intoxication due to their low educational backgrounds and the lack of protection measures.

Another strategy used by maize farmers in the Volta Region to reduce the negative impact of climate change is changing or timing planting dates. This has become necessary due to the fact that prediction of when and how long rainfall will occur has now become extremely difficult to the farmers. They will rather had to wait until whenever the rain starts before they will be able to start planting. On the average, about 60 percent of the farmers in the region have resorted to this strategy, though it varied within the geographical locations. For instance, while more than 4 out of every 5 farmers in the south adopt this strategy, only about 2 out of 5 farmers in the middle zone were engaged in such a practice. For those in the northern part of the region, 54.1 percent were using such a practice to reduce crop failure due to unfavourable weather conditions. It could be observed that those areas where more and more farmers are adopting this strategy are the worst hit in terms of climate change impact. There are some places where it has become necessary for them to plant early to avoid drought, there were other places where the farmers had to wait for more than a month before planting due the fact that the onset of rain did not occur as it supposed.

Integrated soil fertility management is a set of practices that include the use of both mixed cropping with leguminous crops, application of both organic and inorganic fertilizers, and use of certified seeds combine with selected agronomic practices to optimize resource use and increase productivity. The study reveals that majority of the farmers in the northern zone (50.8%) were using ISFM practices to reduce the impact of climate change effects while about 80 percent of farmers from the southern zone were adopting it. For those in the middle zone, less than half of them (46.1%) were using the ISFM strategies. As indicated by Vanlauwe, et al. (2012), ISFM options available to a specific household will depend on the resource endowment of that household and soil fertility status of the land use for production. However, key components that will lead to better soil fertility management needs to be incorporated. In areas, for instance, where farmyard manure is targeted towards specific fields within a farm, local adaptation is already taking place, even if no fertilizer is used, as is the case in much of southern zone. This could be one of the reasons why most farmers from the south have been using the ISFM. For a significant improvement in eco-efficient crop productivity, an enhanced supply of nutrients has to go hand in hand with a greater demand by the crop. Applying fertilizer to germplasm that is unresponsive, not adapted to the environment, or that is affected by pests and diseases will result in low agronomic efficiency values (Vanlauwe, et al., 2012). The integrated soil fertility management practices include zero tillage or conservation tillage, use of organic and inorganic fertilizers and other agrochemicals, application of fertilizer same day of planting, and other land management regimes to increase yield and improve soil fertility. Most respondents who used the application of fertilizer same day of planting indicated that it helps the plants to grow faster and outwit the weeds. It was also reported that, pest and diseases attack are minimized if this is done.

Almost a quarter of the maize-farming households employed crop diversification for reducing the negative impact of the climate change. As indicated by Kergna and Dembélé (2018) crop diversification and intensification make food available to population and production of high value crops. Increased and diversified crop production make food prices stable and low, therefore enhance food security. Better and affordable food improves nutrition and health.

Only a few of the maize farmers were practicing agroforestry or left fields trees that they thought are of high value or important in terms of nutrition, health, animal feed or land protection. As posited by Kergna and Dembélé (2018), agroforestry could enrich the soil, improve food security and alleviate poverty, and it is highly related to climate change. A substantial number of the maize farmers in the Volta Region practised seed priming in their Maize farming system. This is more prominent in the Middle and Southern zone where the attested to the fact that seed priming is very effective, more especially during periods when moisture is not enough or does not last long in the soil. The technology allows seed to germinate early and improve germination rate (Kergna and Dembélé, 2018).

As indicated by Abdoulaye, Bamire, Akinola and Etwire (2017) farmers employed different strategies to assuage negative climate change effects. The top three strategies identified by Abdoulaye et al. (2017) in the Brong Ahafo and Upper West Region of Ghana were changing planting dates, growing different crops or engaging in mixed cropping to reduce the likelihood of total crop failure, and using drought tolerant maize or early maturing crop varieties. The result of this current study showed majority of the respondents not using mixed cropping systems (52.7%). However, on the bases of site specifics, the 81.1 percent of the farmers in the Southern Volta were practicing mixed cropping. Only about a quarter of those from the Northern Volta were into mixed cropping while a little more than a third (35.2%) of those in the Middle Volta were practicing mixed cropping. On the ecological dimension, intensive monocropping in pursuit of economies of scale is prone to a significant biodiversity loss. It is also susceptible to several unintended ecological outcomes like pest outbreaks that arise from reduced environmental opportunities for natural enemies and transformation of pest genetics to resist frequently used pesticides. Crop failures due to such ecological chaos may lead to a severe economic loss and serious debt problems for less affluent farmers (Murray 1994; Wright 2005; Amekawa, 2010).

The average number of adaptation strategies employed by the farmers to combat climate change effects was 5.34. The mean figures vary within the various geographical zones in the region. The farmers from the middle zone were adopting, on the average, 4.42 response strategies. This was significantly lower than those farmers from the Northern zone (5.38) which was also significantly lower than Southern zone (6.23). All these averages were greater than that of Abdoulaye et al.

(2017), who reported that farmers generally employed three main adaptation strategies to deal with climate change risks in the Brong Ahafo and Upper West Regions on Ghana. The use of DT or early maturing crop varieties as an adaptation strategy ranked second in Upper West and third in Brong Ahafo.

Factors Associated with Farmers' Perceptions and Response Strategies to Climate Change Effects

Frequency and severity of extreme climate events such as droughts and floods will have precarious corollaries. This could increase the number of people at risk of hunger and livelihood security. Although there are a number of empirical studies on patterns of climate change in sub Saharan Africa, few of these studies tried to study factors associated with farmers' perception and response strategies to climate change. In addition to institutional and social innovation at the global governance level, changes in demographics, consumption, behaviour, attitudes, education, institutions, and socially embedded technologies are all important to maximize the chances of achieving a Stabilized Earth pathway (Westley, et al., 2011; Steffen, et al., 2018). Table 52 presents findings of the relationships between socio-economic factors, and farmers perceived effects of climate change and response strategies adopted to avert the negative effects.

Sex of respondents have negative and significant association with perception of climate change effects; an indication of the fact that female maize farmers tend to be more negative effect of climate change impact than their male counterparts. However, male farmers tend to adopt significantly higher number of adaptation strategies than female farmers. Maize farmers who were married tend to have more adaptive capacity than what unmarried maize farmers do. Though age was not significant for both effects and adaptive capacity, there were positive associations.

Table 52: Factors associated with farmers' perceptions and response strategies to climate change effects

Variables	Climate change effects	Response strategies
Sex of respondents	-.075*	.153**
Marital status	-.043	.105**
Age of farmer	.017	.033
Years in formal education	.155**	.262**
Household size	-.015	.054
Experience in maize farming	.020	.111**
Engaged in non-farm activities	.089*	.217**
Farm size	.049	.247**
Planting in both season	.089*	.215**
Total yield	.099*	.256**
Multiple cropping	.096*	.324**
Frequency of weed control	.154**	.135**
Access to credit	.189**	.184**
Land tenure security	.005	.181**
Access to labour	.074	.153**
Access to extension services	.125*	.225**

Source: Field survey, Akaba (2018)

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Both climate change effects and adaptive capacity have positive and significant association with number of years in formal education. Maize farming experience by the farmers was also positive with climate change effects and adaptive capacity though only the adaptive capacity was significant with experience. Non-farm income generating activities is also positively associated with both effects and adaptive capacity to climate change though they were significant at different levels (alpha levels of .05 and .01 respectively).

Although farm size was not significant with climate change effects, it had positive and significant association with adaptive capacity. While planting in both major and minor seasons, total yield and multiple cropping were significant with climate change effect at .05 alpha levels; they were significant at .01 alpha levels for the adaptive capacity. Access to extension services also had significantly positive associations with both climate change effects and adaptive capacity though at different levels.

It does not matter much when it comes to land tenure security when it comes to climate change effects, however, when it comes to adaptive capacity, those farmers who are more secure with their farm land tend to have higher adaptive capacity than those with unsecure lands. This is similar to the findings on access to labour. Those who could access labour tend to have more adaptive capacity than those who have difficulty in accessing labour, though their climate change effect was not statistically significant.

All these findings in one way or the other support the findings of other researchers from other parts of the world. For instance, a study conducted by Gbetibouo (2009) in South Africa argued that farmers with access to extension services are more likely to perceive changes in the climate because extension services provide information about climate and weather. Consequently, it also indicated that awareness and perceptions of changes in climatic conditions shape action or inaction on the problem of climate change. As argued by Yesuf et al. (2008), households wealth represented by farm and non-farm income increases the likelihood of climate change perception. Maddison (2006) also confirm that farmers with the greatest farming experience were more likely to notice changes in climatic conditions. Moreover, a study conducted by Aemro et al., (2012), cited in Sani and Chalchisa (2016), in Eastern Ethiopia pointed out that sex of household head, frequency of extension contact, access to farmer-to-farmer extension and access to information on climate change were the significant factors that explain farmer's perception of climate change

Different studies conducted in sub-Saharan Africa have used various methods to analyse the factors associated with perceived effects of climate change and choice of adaptation strategies. Different empirical findings confirmed that, demographic factors, such as sex, age of farmers, years of farming experience, household size and years of education, as well as institutional factors such as access to extension services and off-farm income generating activities were identified as significant factors associated with climate change adaptive capacity (Acquah-de Graft & Onumah, 2011; Deressa et al., 2008; Fosu-Mensah et al., 2010; Kurukulasuriya & Mendelson, 2006; Mandleni & Anim, 2011; Mertz et al., 2009). Other studies showed that households with large family size will be more willing to choose the adaptation options such as soil conservation techniques and chemical treatments that are labour intensive (Aymone, 2009; Temesgen et al., 2008). It was also reported by other authors that male-headed household might affect the ability of a household to cope with different climate extreme events (Deressa et al., 2009; Legesse et al., 2013).

Experience in farming increases the probability of uptake of adaptation measures to climate change (Maddison, 2006; Hassan and Nhemachena, 2008; Aymone, 2009; Temesgen et al., 2009). As to the findings of Maddison (2006), educated and experienced farmers are expected to have more knowledge and information about climate change and the agronomic practices that they can use in response. In addition, the same study found that farmers' awareness of changes in climate attributes (temperature and precipitation) is important for adaptation decision making. Moreover, Temesgen et al. (2008) conveyed that education significantly increased soil conservation and changing planting dates as adaptation strategies.

Various studies have shown that the sex is an important variable affecting adaptation decision at the farm level. Temesgen et al. (2009) found that male-headed households adapt more readily to climate change. In contrary to this, Nhemachena and Hassan (2007) found that female-headed households adapt more readily to climate change than male headed household heads.

Large-scale farmers are more likely to adapt to climate change because they have more capital and resources (Hassan and Nhemachena, 2008; Aymone, 2009). Productive resources such as capital, land and labour serve as important factors for coping with and adapting to climate change. The choice of the suitable adaptation measure depends on factor endowments (i.e. family size, land area and capital resources) at the disposal of farming households (Hassan & Nhemachena, 2008). Temesgen et al. (2008) found that in addition to farm income, nonfarm income also significantly increases the likelihood of planting trees, changing planting dates, and using irrigation as adaptation options.

Many researchers have indicated that access to credit increases the likelihood of adaptation (O'Brien et al., 2000; Temesgen et al., 2008; Aymone, 2009; Temesgen et al., 2009). O'Brien et al. (2000) also pointed out that, despite numerous adaptation options that farmers are aware of and willing to apply, the inadequate access to financial resources to purchase the necessary inputs and other associated equipment (e.g., purchasing seeds, acquiring transportation, hiring temporary workers) is one of the significant constraints to adaptation. Furthermore, the majority of the farmers in Limpopo basin of South Africa cited lack of financial resources as the main constraint to adaptation (Aymone, 2009).

Many studies have confirmed that having better access to extension services increases the probability of adopting different adaptation measures (Aymone, 2009; Temesgen et al., 2009). Farmers with better extension services access are more likely to be aware of changing climatic conditions and expected to have good knowledge about different types of adaptation measures in order to reduce climate change impact or to exploit the advantages. Information on climate change impact also increases the likelihood of using different crop varieties as an adaptation measure. Having access to farmer-to-farmer extension increases the likelihood of using different crop varieties and planting trees (Temesgen et al., 2008).

Aemro et al., (2012) showed that the sex of the household head, age of the household head, education of the household head, family size, non/off-farm income, access to credit, access to farmer-to-farmer extension, access to climate information, and extension contact have a significant impact on choices of climate change adaptation strategies. In addition, Belaineh et al., (2013) identified that sex, plot size and frequency of extension contacts have a significant and positive impact on crop based diversification coupled with soil and water conservation practices. Seid et al., (2016) also pointed out that sex of the household head, literacy status, farming experience, family size, land holding, access to credit, access to media, extension contact, farmer to farmer extension, farm income, off/non-farm income and access to training have a statistically significant impact on climate adaptation strategies (Sani & Chalchisa, 2016)

Summary

This chapter presented findings on the response strategies employed to deal with climate change effects in the study area. Chapter six has empirically established the levels of adaptive capacity of the maize-farming households to climate change shocks and effects. The main issues presented in this chapter included perceptions of farmers in changes in temperature and precipitation as proxy for climate change, effects of changes in temperature and precipitations on their farming enterprises and response strategies adopted by the maize-farming households in dealing with the negative impacts of the changes. The chapter also estimated farm- and farmer-specific factors associated with perceptions and response strategies toward climate change effects using correlations.

CHAPTER SEVEN

MODELS FOR IMPROVING CLIMATE CHANGE RESPONSES, FOOD SECURITY AND MAIZE PRODUCTION SUSTAINABILITY

Introduction

This section presents results from the current study. In the first part of this chapter, descriptive statistics were used to describe the characteristics of the data collected. The second part of the chapter then uses Structural Equation Modelling to test the proposed research model. In performing the SEM analysis the two stage process recommended by Chin (1998) was employed. Firstly, the measurement model (outer model) was assessed and found to be reliable and valid. Secondly, the structural model was also assessed to evaluate the causal relationships between the variables in the proposed model. The effects of moderating and mediating variables were also tested. In addition, the quality of the model was also assessed using the Coefficient of determination R^2, Predictive Relevance Stone-Geisser Q^2 and model fit indices.

Preliminary Examination of the Data

In order to ensure that the data is suitable for statistical analysis and produces meaningful results, a preliminary examination of the data was conducted (Sekaran & Bougie, 2010). Preliminary examination of the data provides researchers a comprehensive means to explore the individual variables and the relationships between these variables. Preliminary data analysis is seen here as complementary to empirical analysis and not a replacement (Hair, Black, et al., 2014). The preliminary analysis includes checking the accuracy of the data input, detecting and treating outliers and missing values and testing the assumptions of the multivariate statistical technique being employed. In this study, the researcher screened the data to ensure accuracy and treated outliers and missing values. To justify the use of PLS-SEM, the data was also tested for normality.

Ensuring accuracy of data input

After collecting the paper-based structured interview schedule, the responses were coded and entered into IMB-SPSS version 21. A total of 765 respondents completed the survey, however, 733 were used for data analysis. The relatively high response rate (95.8%) was due to strategically recruiting and training field research assistants and the extension agents who assited in the data collection and also through the hard work of the research assistants recruited and effective supervision of the data collection processes. The data from the paper-based instrument was however prone to some errors that may have occurred during the process of entering the data. In order to be able to go back and verify the data that was entered all the paper-based instrument were numbered. Descriptive statistics of the data were generated, and based on these statistics the data was screened for errors. Since the items on the latent variables used in the research instrument were measured within specific intervals or ranges any entry that was above or below the expected interval or range was flagged. The maximum values, minimum values and the means for items were used to detect any discrepancies in the entry of the data and corrections were made by re-entering the right values.

Evaluating the quality of data by assessing outliers

Outliers can be defined as "observations with a unique combination of characteristics identifiable as distinctly different from the other observations" (Hair, Black, et al., 2014, p. 62). Outliers are cases in the data that have values which are inconsistent with the majority of cases in the dataset. Identifying and treating outliers is very important since their inclusion in the data set may result in incorrect decisions about the analysis. The researcher checked for both univariate and multivariate outliers. In checking for univariate outliers, each indicator variable was examined and values that fell out of range were eliminated. IBM SPSS was used to convert all indicator variables into standardized z-scores. As a rule, z-score values greater than ±3.29 indicates outlier (Field, 2013). In the current study, those items which had absolute z-scores values beyond ±3.29 were subsequently deleted from the dataset.

Multivariate outlier assessment was also performed, since values that may not be outliers themselves may turn out to be multivariate outliers when they are combined with other variables. In assessing multivariate outlier, the Mahalanobis distance D^2 was used. The Mahalanobis distance is a measure of each observation's distance in multidimensional space from the mean center of all observations. As a rule, an observation is flagged if the probability of the Mahalanobis distance is greater than 0.001. The use of this criterion also found 2 multivariate outliers which were subsequently deleted from the dataset.

Evaluating the quality of data by assessing missing values

Missing data occurs when some information for a particular case or subject is not available for a subject (or case) but other information about the subject or case is available. Missing data can occur due to the failure of respondents to answer one or more questions in a survey or due to data entry errors. Missing data could be random or non-random. Non-random missing data could lead to erroneous results. In the current study 32 cases were deleted because they had significant missing data. From Table 53 it can be seen that some other items had some missing values. However, these missing values were not significant. These missing values were treated using the median of nearby points replacement method implemented in the IBM-SPSS analysis software (Field, 2013).

Table 53: Descriptive summary of the indicators for the PLS-SEM analysis

Indicator variables	Description of the variables	No.	Missing	Mean	Median	Min	Max	St. Dev.	Excess Kurtosis	Skewness
CCE_Temp	Number of temperature effects	1	0	5.424	5.00	2.00	9.00	1.521	-0.751	-0.0
CCE_Precip	Number of precipitation effects	2	0	5.198	5.00	1.00	8.00	1.673	-0.944	-0.003
CCR_Moist_Drout	Response to extreme moisture/drought	3	0	0.534	0.55	0.12	0.83	0.162	-0.590	-0.351
CCR_Yield	Response to yield reduction	4	0	0.495	0.52	0.12	1.00	0.172	-0.684	-0.152
CCR_Weed	Response to weed control	5	0	0.499	0.50	0.09	1.00	0.179	-0.748	0.036
CCR_Soil	Response to loss of soil nutrients	6	0	0.549	0.53	0.13	1.00	0.181	-0.440	-0.199
CCR_Dise_Pest	Response to increased diseases and pest outbreak	7	0	0.487	0.52	0.09	0.86	0.173	-0.499	-0.421
CCR_Vegetn	Response to loss of vegetation	8	0	0.486	0.52	0.12	1.00	0.182	-0.938	-0.184
CCR_Fld_Erosn	Response to loss of soil to flood/erosion	9	0	0.520	0.56	0.11	0.88	0.154	-0.522	-0.290
CCR_Postharv	Response to difficulty in postharvest handling	10	0	0.7	0.	0.10	0.89	0.167	-0.824	-0.138
LivDiv_Variety	Variety diversification	11	0	1.960	2.00	1.00	4.00	0.751	-0.781	0.220
LivDiv_Crops	Crop diversification	12	0	3.367	3.00	1.00	7.00	1.006	-0.029	0.399
LivDiv_incom	Income diversification	13	0	1.892	2.00	1.00	3.00	0.570	-0.030	-0.007
ASA1	Attitude towards intercropping	14	11	7.345	8.00	1.00	10.00	2.317	-0.857	-0.456
ASA2	Attitude towards cover cropping	15	5	7.540	8.00	1.00	10.00	2.317	-0.540	-0.716
ASA3	Attitude towards crop rotation	16	0	7.126	7.00	2.00	10.00	2.281	-1.016	-0.290
ASA4	Attitude towards row banding of herbicides	17	0	7.207	8.00	1.00	10.00	2.183	-0.820	-0.342

Table 53 continued

Variables	Description of the variables	No.	Missing	Mean	Median	Min	Max	St.Dev.	Kurtosis	Skewness
ASA5	Attitude towards integrated pest management	18	8	7.229	8.00	2.00	10.00	2.140	-0.830	-0.357
ASA6	Attitude towards use of green manure	19	0	7.492	8.00	1.00	10.00	2.043	-0.617	-0.507
ASA7	Attitude towards use of animal manure	20	0	7.867	8.00	1.00	10.00	2.195	0.132	-0.949
ASA8	Attitude towards reduced rates of herbicides	21	12	7.065	7.00	1.00	10.00	2.425	-0.749	-0.579
ASA9	Attitude towards reduced nitrogen fertilizer rates	22	9	6.9	7.00	1.00	10.00	2.517	-0.9	-0.295
ASA10	Attitude towards reduced use of fertilizers	23	0	6.900	7.00	1.00	10.00	2.454	-0.979	-0.231
ASA11	Attitude towards reduced tillage	24	0	6.192	6.00	1.00	10.00	2.737	-1.005	-0.170
ASA12	Attitude towards recycling agricultural wastes	25	15	7.370	8.00	1.00	10.00	2.513	-0.243	-0.771
ASA13	Attitude towards biological control of weed and pests	26	18	7.400	8.00	1.00	10.00	2.7	0.204	-0.969
SA_Pr	Profit/economic sustainability index	27	0	0.601	0.65	0.10	1.00	0.167	-0.538	-0.258
SA_Pl	Planetary/environmental sustainability index	28	0	0.583	0.60	0.20	1.00	0.144	-0.513	0.079
SA_Pe	People/social sustainability index	29	0	0.663	0.71	0.14	1.00	0.156	0.003	-0.559
Pdn_const	Number of production constraints	30	0	5.408	5.00	1.00	12.00	2.316	0.106	0.620
Ph_const	Number of postharvest constraints	31	0	3.681	4.00	1.00	7.00	1.597	-0.525	0.391
FSI_FCS	Food consumption score	32	0	2.237	3.00	1.00	4.00	1.054	-1.643	-0.198
FSI_FES	Food expenditure share	33	0	2.098	2.00	1.00	4.00	0.841	-0.799	0.212
FSI_LCS	Livelihood-based coping strategy	34	0	1.995	2.00	1.00	4.00	0.868	-1.088	0.262

Source: Field survey, Akaba (2018)

Evaluating the quality of data by assessing normality

A fundamental assumption for most multivariate techniques is the assumption of normality. Normality is the extent to which the data corresponds to the normal distribution. The test of multivariate normality was performed using IBM SPSS version 21. The data being normal meant that the researcher could employ covariance-based SEM, data which is not normal on the other hand is better handled with the variance based SEM.

Table 54: Assessment of multivariate normality for latent variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCCE	.096	733	.000	.971	733	.000
CCR	.048	733	.000	.986	733	.000
LivDiv	.120	733	.000	.964	733	.000
ASA	.052	733	.000	.975	733	.000
SUSAG	.071	733	.000	.986	733	.000
CONST	.117	733	.000	.971	733	.000
FSI	.163	733	.000	.914	733	.000

a. Lilliefors Significance Correction

Source: Field survey, Akaba (2018)

A visual inspection of histogram plots of the data showed that the data was non-normal. Table 53 provides results for the test of univariate normality. From Table 53 it can be seen that data for all indicator variables are negatively skewed except weed control as a response strategy, varietal diversification, crops diversification, planetary sustainable agricultural indicator, production constraints, postharvest constraints, food expenditure share and livelihood-based coping strategy, which are positively skewed. Table 54 also presents results for the test of multivariate normality of latent variables. Results of both the Shapiro-Wilk test and the Kolmogorov-Smirnov test show that the distribution of the data for all latent variables is significantly different from the normal distribution. One justification for the use of PLS-SEM is its ability to model non-normal data (Hair et al., 2017). The use of PLS-SEM in this research is therefore justified by the non-normal nature of the data collected.

Analysis of Partial Least Square Structural Equation Model

The two-step approach to assessing SEM models recommended by Chin (1998) was employed. First the measurement model was assessed to determine the appropriateness of the psychometric properties of the latent variables. In doing so, the researcher assessed the reliability as well as convergent and discriminant validity of the latent variables. Once the measurement model was shown to exhibit sufficient reliability and validity, the researcher went ahead to assess the structural model. The structural model determines whether the structural relations in the hypothesized model are meaningful (Sarstedt et al., 2014). In assessing the structural model, the researcher examined the path coefficients of the hypothesized paths, the predictive power of the models and the fitness of the model.

Measurement model assessment

Reliability

Hair et al. (2014) defined reliability as the degree to which a set of indicators of a latent construct is internally consistent in their measurements. A construct with a high degree of reliability has items that are highly interrelated. In other words reliable constructs have indicators that measure the same thing. The most popular measure of reliability is Cronbach's alpha. However, Chronbach's alpha has been shown to underestimate reliability (Hair, Hult, et al., 2014). This is due to the fact that Chronbach's alpha assumes that all items load equally on the construct. Composite reliability or Dillon-Goldstein's ρ and Dijkstra-Henseler's rho have been proposed as alternatives to Chronbach's alpha. Dijkstra-Henseler's rho is currently the only consistent measure of reliability. Most PLS software provide a measure for Chronbach's alpha and Composite reliability. SmartPLS3 also provides reliability statistics for all three measures. In the current study the researcher provides statistics for all three measures. According to Nunnally and Bernstein (1994) and Henseler, Hubona, and Ray (2016) a construct is deemed reliable if its reliability measure is above 0.7.

From Table 55 the results reveal that the values of both Chronbach's alpha and Dijkstra-Henseler's rho are compellingly higher than the threshold set by Nunnally and Bernstein (1994). Besides, the composite reliability values of all the latent variables are above 0.7 for all constructs. As indicated by Hair, Hult, et al. (2014), composite values between 0.6 and 0.7 are acceptable in a study of this nature. In advanced stages values between 0.7 and 0.9 are preferred (Nunnally & Bernstein, 1994).

Table 55: Reliability Statistics of Latent Variables

Latent Variable	Cronbach's alpha (α)	Dijkstra-Henseler's rho (ρ_A)	Dillon-Goldstein's rho (ρ_c)	Average Variance Extracted (AVE)
ASA	0.919	0.922	0.931	0.531
CCR	0.917	0.922	0.932	0.630
CONST	0.742	0.745	0.885	0.794
FSI	0.798	0.877	0.878	0.707
LivDiv	0.712	0.719	0.838	0.634
PCCE	0.833	0.834	0.923	0.857
SUSAG	0.832	0.835	0.899	0.748

Source: Field survey, Akaba (2018)

However, values less than 0.6 show a lack of reliability, and reliability values greater than 0.95 are undesirables because they indicate that all the items are measuring the same phenomenon and are therefore unlikely to be a valid measure of the construct (Hair, Hult, et al., 2014). It can therefore be concluded that the measurement model for the current study exhibits good reliability, since all the figures were within acceptable range.

Convergent Validity

The convergent validity is the degree to which indicators of a specific construct converge or share a high proportion of variance in common (Hair, Black, et al., 2014). In other words it is the degree to which a measure correlates positively with alternative measures of the same construct (Hair, Hult, et al., 2014). Convergent validity ensures that items assumed to be measuring a particular latent variable measure the said variable and not any other latent variable (Urbach & Ahlemann, 2010).

Convergent validity was assessed using the Average Variance Extracted (AVE) measure and factor loadings of items. AVE measures the amount of variance that the latent variable captures from the items it measures relative to the amount of variance associated with the measurement errors (Aibinu & Al-Lawati, 2010). As a rule of thumb AVE values must be greater than 0.5 to indicate convergent validity (Hair et al., 2011). This means that at least 50% of the measurement variance is captured by the latent variables. From Table 55 it can be seen that AVE values range from 0.531 for attitudes towards sustainable agriculture to 0.857 for perceived climate change effects on maize production. It is therefore concluded that evidence of convergent validity is shown since the AVE values of all latent variables are well above the cut-off point of 0.5.

Discriminant validity

Hair, Black, et al. (2014) described discriminant validity as the extent to which a construct is truly distinct from other constructs both in terms of how much it correlates with other constructs and how distinctly measured variables represent only this single construct. In assessing discriminant validity the following guidelines were followed: (1) the loadings of each indicator should be greater than all its cross-loadings (Chin, 1998; Götz, Liehr-Gobbers, & Krafft, 2010; Henseler et al., 2009), (2) the Fornell- Larker criterion; which states that the Average Variance Extracted (AVE) of each latent construct should be greater than the highest squared correlations between any other construct (Fornell & Larcker, 1981), and (3) the Heterotrait-Monotrait (HTMT) criterion proposed by Henseler, Ringle, and Sarstedt (2015), which state that all HTMT ratios of correlation must be less than 0.85.

Careful evaluation of the results in Table 56 show that, all indicator variables load highest on their respective constructs (values shown in bold); and that no indicator loads higher on other constructs than on its own intended construct. From Table 57, it can also be seen that the Fornell-Larcker criterion is also met in that, the square root of the AVE for each construct is greater than the cross-correlation between the construct and any other construct. Results from Table 58 also show that the $HTMT_{85}$ criterion has been met since all the values in that table are less than 0.85. It can therefore be concluded that the measurement model shows evidence of discriminant validity.

Collinearity has classically been defined as a predictor-predictor phenomenon in multiple regression models. In this traditional perspective, when two or more predictors measure the same underlying construct, or a facet of such construct, they are said to be collinear (Kock, 2015). Full collinearity VIFs tend to increase with model complexity, in terms of number of latent variables in the model, because: (a) the likelihood that questions associated with different indicators will overlap in perceived meaning goes up as the size of a research instrument increases, which should happen as the number of constructs covered grows; and (b) the likelihood that latent variables will overlap in terms of the facets of the constructs to which they refer goes up as more latent variables are added to a model (Kock, 2015).

Table 56: Test of Discriminant Validity using Indicator Loadings with Cross Loadings, and the Variance Inflation Factor (VIF)

Indicator variables	CONST	LivDiv	PCCE	ASA	CCR	FSI	SUSAG	*VIF*
Pdn_const	**0.901**	-0.190	0.049	-0.317	-0.218	0.452	-0.341	*1.532*
Ph_const	**0.881**	-0.206	0.000	-0.316	-0.214	0.408	-0.267	*1.532*
LivDiv_Crops	-0.201	**0.826**	0.124	0.223	0.202	-0.332	0.163	*1.442*
LivDiv_Variety	-0.176	**0.799**	0.089	0.140	0.242	-0.3	0.161	*1.356*
LivDiv_incom	-0.1	**0.762**	0.123	0.131	0.230	-0.261	0.103	*1.392*
CCE_Precip	0.030	0.145	**0.924**	0.021	0.6	-0.187	0.085	*2.042*
CCE_Temp	0.023	0.114	**0.928**	0.040	0.490	-0.195	0.100	*2.042*
ASA1	-0.302	0.202	0.087	**0.707**	0.275	-0.359	0.366	*1.960*
ASA3	-0.330	0.217	0.007	**0.786**	0.205	-0.398	0.386	*2.815*
ASA4	-0.317	0.215	0.050	**0.804**	0.266	-0.400	0.449	*2.590*
ASA5	-0.290	0.160	0.009	**0.761**	0.214	-0.328	0.368	*2.598*
ASA6	-0.300	0.182	0.092	**0.775**	0.258	-0.407	0.444	*2.142*
ASA7	-0.206	0.111	-0.016	**0.731**	0.122	-0.302	0.338	*2.052*
ASA8	-0.226	0.119	0.032	**0.758**	0.119	-0.303	0.404	*2.335*
ASA9	-0.261	0.111	-0.009	**0.738**	0.156	-0.310	0.445	*2.486*
ASA10	-0.222	0.142	0.018	**0.703**	0.155	-0.294	0.410	*2.185*
ASA11	-0.177	0.162	0.056	**0.645**	0.194	-0.409	0.361	*1.842*
ASA12	-0.227	0.124	-0.040	**0.687**	0.098	-0.356	0.420	*2.451*
ASA13	-0.204	0.0	-0.024	**0.628**	0.134	-0.295	0.429	*1.985*

Table 56 continued

CCR_Dise_Pest	-0.023	0.181	0.480	0.002	**0.749**	-0.288	0.108	*2.573*
CCR_Fld_Erosn	-0.259	0.253	0.379	0.311	**0.837**	-0.501	0.330	*2.695*
CCR_Moist_Drout	-0.371	0.312	0.297	0.306	**0.739**	-0.602	0.240	*1.832*
CCR_Postharv	-0.153	0.179	0.469	0.139	**0.795**	-0.378	0.237	*2.414*
CCR_Soil	-0.136	0.225	0.430	0.183	**0.810**	-0.438	0.217	*2.402*
CCR_Vegetn	-0.255	0.215	0.409	0.359	**0.810**	-0.497	0.332	*2.283*
CCR_Weed	-0.110	0.191	0.445	0.100	**0.795**	-0.350	0.161	*2.513*
CCR_Yield	-0.104	0.183	0.465	0.079	**0.808**	-0.373	0.180	*2.655*
FSI_FCS	0.315	-0.251	-0.061	-0.276	-0.322	**0.769**	-0.201	*1.564*
FSI_FES	0.540	-0.419	-0.269	-0.487	-0.612	**0.904**	-0.403	*1.797*
FSI_LCS	0.302	-0.292	-0.132	-0.403	-0.402	**0.844**	-0.351	*1.831*
SA_Pe	-0.435	0.113	0.018	0.492	0.201	-0.316	**0.853**	*1.787*
SA_Pl	-0.251	0.178	0.134	0.510	0.307	-0.361	**0.889**	*2.119*
SA_Pr	-0.195	0.183	0.108	0.427	0.264	-0.348	**0.852**	*1.927*

Source: Field survey, Akaba (2018)

The occurrence of a VIF greater than 3.3 is proposed as an indication of pathological collinearity, and also as an indication that a model may be contaminated by common method bias. Therefore, if all VIFs resulting from a full collinearity test are equal to or lower than 3.3, the model can be considered free of common method bias. As posited by (Hair, Hult, Ringle, & Sarstedt, 2017), VIF values of 5 and higher indicate a potential collinearity problem and the researcher may also consider removing indicators. The last column of Table 56 shows the VIFs obtained for all the latent variables in the models. Based on this premise, it could be concluded that none of the indicator variables show evidence of collinearity since the VIF for all the latent variables in the model were below the threshold of 3.3.

Table 57: Test of Discriminant Validity using the Fornell-Larker Criterion

	ASA	CCR	CONST	FSI	LivDiv	PCCE	SUSAG
ASA	**0.729**						
CCR	0.257	**0.793**					
CONST	-0.355	-0.242	**0.891**				
FSI	-0.480	-0.558	0.483	**0.841**			
LivDiv	0.210	0.281	-0.221	-0.397	**0.796**		
PCCE	0.033	0.522	0.028	-0.206	0.139	**0.926**	
SUSAG	0.553	0.298	-0.343	-0.395	0.182	0.100	**0.865**

Note: Square root of AVEs are shown in the diagonal (**bold**)

Source: Field survey, Akaba (2018)

The discriminant validity assessment has the goal to ensure that a reflective construct has the strongest relationships with its own indicators in the PLS path model (Hair, Hult, Ringle, & Sarstedt, 2017). Once reliability, convergent validity and discriminant validity of the measurement model have been achieved, the researcher can now go ahead to test the significance of the structural paths in the proposed research model.

Table 58: Test of Discriminant Validity Using the Heterotrait-Monotrait Ratio

	ASA	CCR	CONST	FSI	LivDiv	PCCE	SUSAG
CCR	0.262						
CONST	0.425	0.273					
FSI	0.534	0.596	0.593				
LivDiv	0.250	0.340	0.302	0.499			
PCCE	0.061	0.607	0.038	0.224	0.182		
SUSAG	0.630	0.325	0.430	0.463	0.233	0.120	

Source: Field survey, Akaba (2018)

Structural model assessment

Once the psychometric properties of the measurement model were confirmed to be acceptable, the structural model was conducted (Figure 6). The assessment of the structural model was based on the sign, magnitude and significance of path coefficients of each hypothesized path. In order to determine the significance of each estimated path, the bootstrapping procedure was used with 5000 resamples drawn with replacement (Figure 7). The predictive power together with the predictive relevance of the estimated models was also assessed using the Coefficient of determination and the Stone-Geiser Q^2 respectively. Model Fit indices such us the Standardized Root Mean Square Residual (SRMR) composite factor model (Henseler et al., 2014), the Geodesic Discrepancy d_G, the Unweighted Least Squares Discrepancy d_ULS (Dijkstra & Henseler, 2015), the average R-squared, the average path coefficient (Kock, 2013) and the Tenenhaus Goodness of Fit index, GoF (Tenenhaus, Amato, & Vinzi, 2004) were also used to assess the fitness of the estimated model. Lastly an Importance-Performance Matrix Analysis (IPMA) was performed to determine the relative importance of the factors that explained each of the endogenous variables in the structural model.

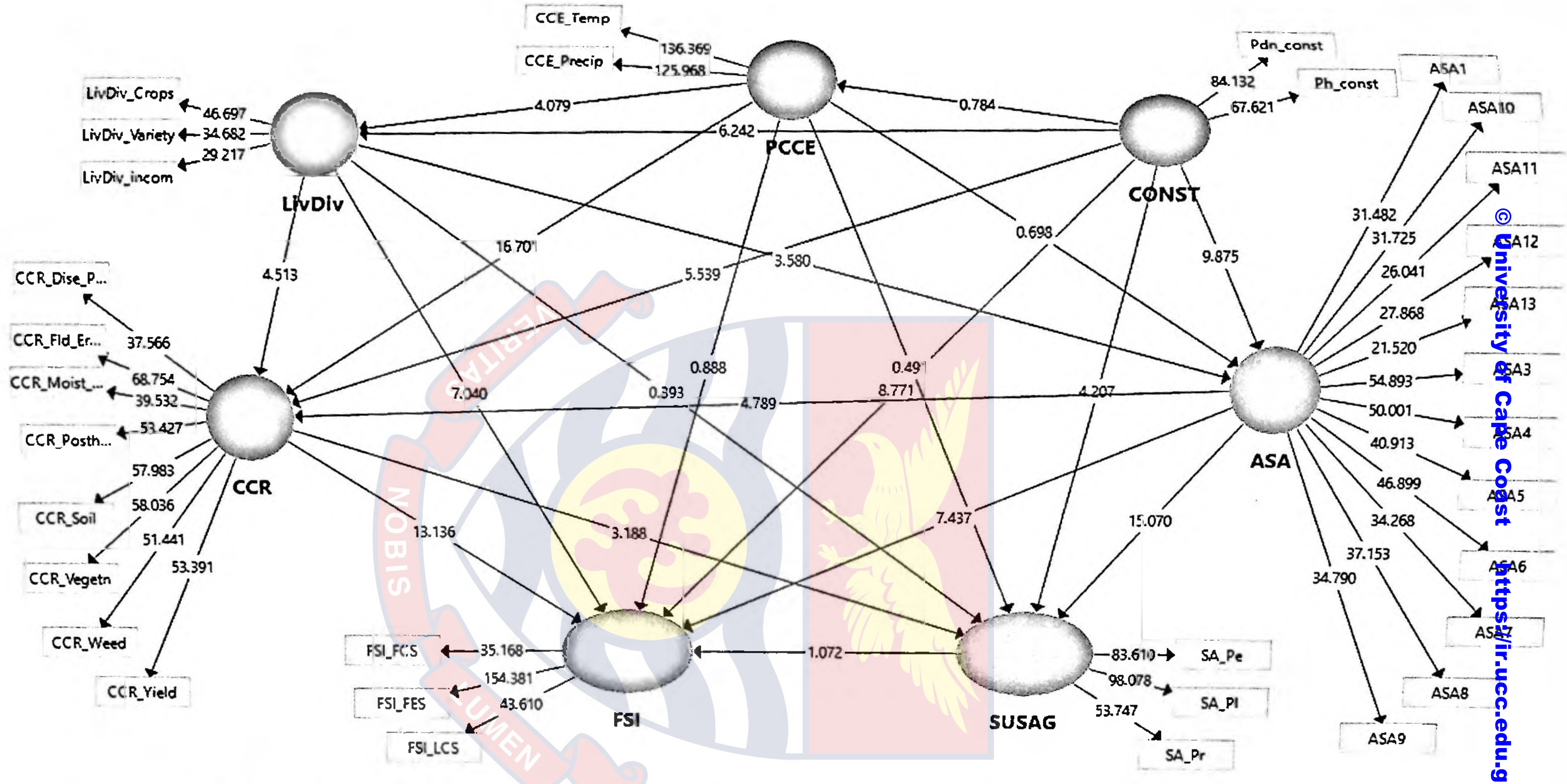

Figure 6: Structural equation model developed for climate change responses, food security and maize production sustainability

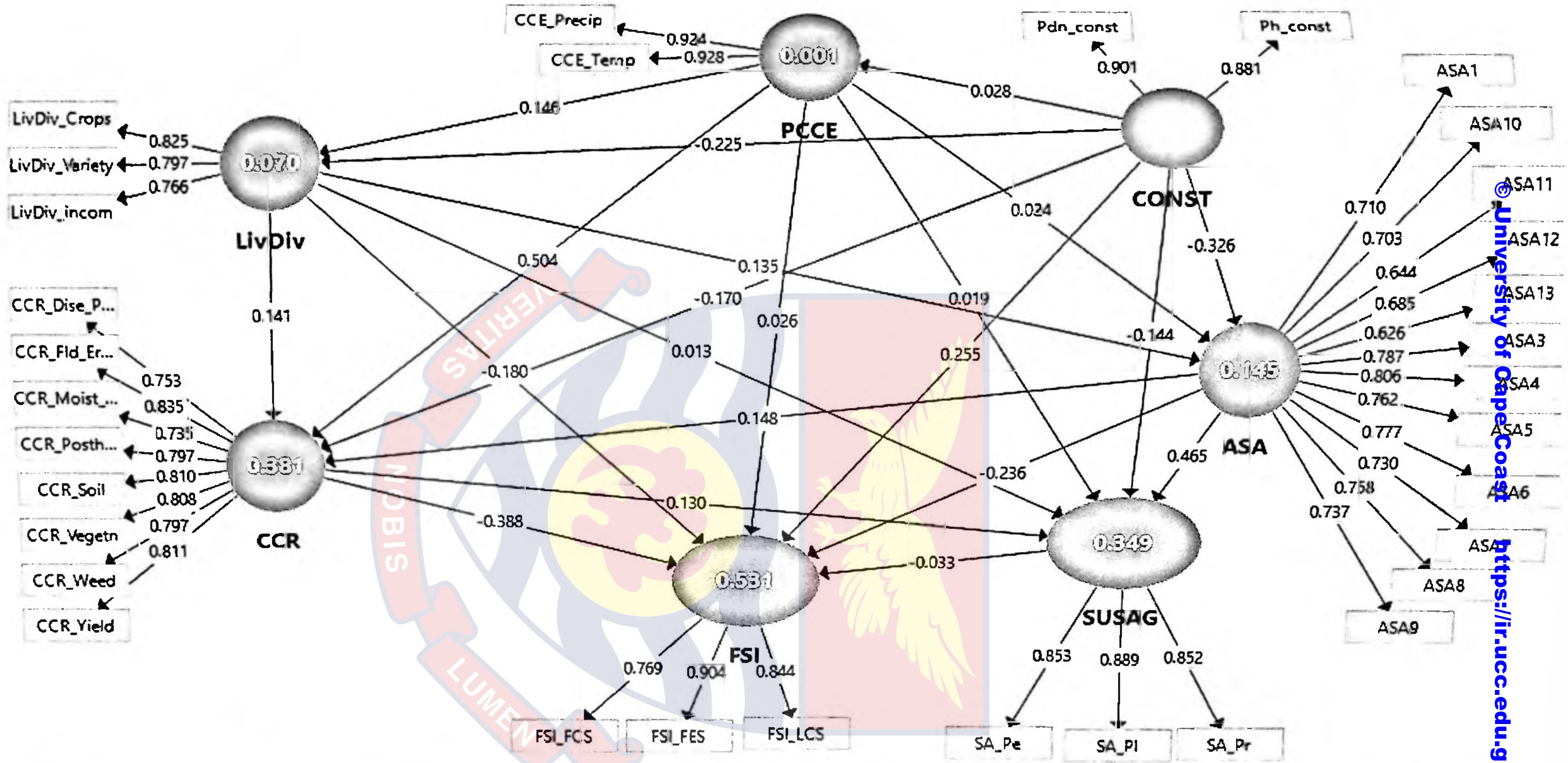

Figure 7: Structural equation model developed for the determinants of climate change responses, food security and maize production sustainability

Hypotheses Testing

It was posited in Chapter 2 that constraining factors will increase climate change effects (H_1). From Table 59 it can be seen that even though the relationship between constraining factors and perceived climate change effect was positive, it was however, not significant ($\beta = 0.028$, $p = 0.433$). This implies that an increase in the number and complexity of constraining factors does not necessarily influence the perception of the maize farmers on the climate change effect. Thus reducing the number of constraining factors to maize production may not change farmers' perception about how climate change is impacting negatively on their farming activities. The hypothesized effect was therefore not supported.

Hypothesis 2 stated that the constraining factors have negative and significant relationship with climate change response strategies adopted by the Maize farming households. The results from Table 59 are consistent with the earlier expectation as the constraining factors to maize production was found to have a significant relationship on climate change response strategies (β=0.170, $p = 0.000$). This means that standardized unit increase in constraining factors would result in a 17 percent reduction in maize farmers efforts and strategies to deal with climate change effects in their farming activities. The hypothesized effect was therefore supported.

Hypothesis 3 stated that there was a significant and negative relationship between constraining factors and attitudes of farmers towards sustainable agriculture. The results indicated consistency in the expectation of the hypothesised relationship between constraining factors and attitudes of farmers towards sustainable agriculture ($\beta = -0.326$, $p = 0.000$). This implies that a reduction in the number of constraining factors to maize production could enhance the attitudes of farmers towards sustainable agriculture to about a third of the standard unit. The hypothesised effect was therefore supported.

Hypothesis 4 proposed significant and negative relationship between constraining factors and livelihood diversification of Maize farming households. Consistent to the proposed hypothesis, constraining factors was found to have negative significant relationship with livelihood diversification (β = -0.225, p = 0.000). This result indicates that reducing the constraining factors to maize production enterprise in the study area could increase livelihood diversification either in the number of maize varieties, number of crops been produced or alternative income generation activities outside farming. In other words, farmers tend to avert myriads of challenges in their maize production enterprises by involving in number of livelihood diversification activities. The hypothesized effect was therefore supported.

The assertion of hypothesis 5 was that the constraining factors to maize production enterprise in the study area significantly affect sustainable agricultural practices among the maize farmers. As posited, constraining factors was found to have a significantly negative relationship with sustainable maize production practices (β = -0.144, p = 0.000). The result implies that a unit reduction in constraining factors to maize production is expected to result in about a marginally 14.4 percent increase in farmers' practices of sustainable agriculture on their maize farms. The results therefore provide support for hypothesis H_5.

In hypothesis H_6 the study made a proposition that constraining factors will increase food security index of Maize farming households. Consistent with the earlier position, constraining latent variable was found to be a positive significant predictor of food insecurity index (β = 0.255, p = 0.000). It can therefore be inferred that a unit reduction in the constraining factors to maize production could reduce food insecurity by 25.5 percentage points. In other words, the finding suggests the supposition that food security will increase if the level of constraints in the maize enterprises is reduced.

Hypothesis 7 advances the argument that the perception of maize farmers on climate change effects will increase their adaptation strategies to climate change. Consistent with the earlier position, perceived climate change effects was found to be a significant predictor of response strategies. The result corroborates the assertion that those farmers who experience more intense climate change effect will adopt a number of strategies that they hope will alleviate the deleterious effects of climate change (β = - 0.504, p = 0.000). The perception of climate change effects was found to have a positive effect on responses to climate change. The result implies that farmers who claimed to have had several areas of their farming activities been affected by the negative impacts of climate change tend to adopt more response strategies than those who experienced less of the climate change effects. In fact, climate change effect was found to be the most significant predictor of climate change response. Thus a unit change in the perception of climate change effect would lead to more than 50 percent change in the number of adaptation strategies employ by maize farmers to survive their farming business. This is not surprising because these two latent variables are all related directly as far as climate change effect and adaptation strategies are concerned. Ability of farmers to reduce the negative effects of climate change would lead to adoption of several strategies if they still want to get substantial amount of dividend from their farming enterprises. The hypothesis is therefore supported. This finding supports the assertion by Madison (2006) that high perception of climate change had significant and positive influence on adaptative capacity of farmers.

In hypothesis 8, perceived climate change effect was envisaged to have negative and significant relationship with farmers' attitudes towards sustainable agriculture. Contrary to the expectation, the relation was positive and insignificant. Thus, those farmers who perceived higher climate change effects on their maize farms tend to have positive attitudes towards sustainable agriculture (β = - 0.024, p = 0.485).

Table 59: Results of Hypothesis Testing

	Hypotheses	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	p-Values	Remarks
H1	CONST -> PCCE	0.028	0.027	0.036	0.784	0.433	Not Supported
H2	CONST -> CCR	-0.170	-0.170	0.031	5.539	0.000	Supported
H3	CONST -> ASA	-0.326	-0.327	0.033	9.875	0.000	Supported
H4	CONST -> LivDiv	-0.225	-0.227	0.036	6.242	0.000	Supported
H5	CONST -> SUSAG	-0.144	-0.144	0.034	4.207	0.000	Supported
H6	CONST -> FSI	0.255	0.254	0.029	8.771	0.000	Supported
H7	PCCE -> CCR	0.504	0.503	0.030	16.701	0.000	Supported
H8	PCCE -> ASA	0.024	0.024	0.035	0.698	0.485	Not Supported
H9	PCCE -> LivDiv	0.146	0.1	0.036	4.079	0.000	Supported
H10	PCCE -> SUSAG	0.019	0.020	0.038	0.491	0.624	Not Supported
H11	PCCE -> FSI	0.026	0.026	0.029	0.888	0.375	Not Supported
H12	LivDiv -> CCR	0.141	0.141	0.031	4.513	0.000	Supported
H13	LivDiv -> ASA	0.135	0.136	0.038	3.580	0.000	Supported
H14	LivDiv -> SUSAG	0.013	0.014	0.034	0.393	0.695	Not Supported
H15	LivDiv -> FSI	-0.180	-0.180	0.026	7.040	0.000	Supported
H16	ASA -> CCR	0.148	0.149	0.031	4.789	0.000	Supported
H17	ASA -> SUSAG	0.465	0.465	0.031	15.070	0.000	Supported
H18	ASA -> FSI	-0.236	-0.236	0.032	7.437	0.000	Supported
H19	CCR -> SUSAG	0.130	0.129	0.041	3.188	0.001	Supported
H20	CCR -> FSI	-0.388	-0.388	0.030	13.136	0.000	Supported
H21	SUSAG -> FSI	-0.033	-0.032	0.030	1.072	0.284	Not Supported

Source: Field survey, Akaba (2018)

This finding therefore implies that, the perceptions of the farmers may not necessarily influence their attitudes towards sustainable agricultural practices. This could also be attributed to the fact that since these farmers have experienced and felt the need to avert the deleterious effect on climate change, they are rather the proclivity towards sustainable production which could reduce the extreme climate variability and its effect on agriculture. The hypothesis is therefore not supported.

In hypothesis 9, it was proposed that the farmers perceived effects of climate change on their farms has a positive effect on engaging in livelihood diversification activities such as planting of different maize varieties or planting different crops so that in terms of crop failure of one crop or the other, there will get some form of cushioning from other crops. As expected, climate change effect was found to have a positive significant relationship with livelihood diversification ($\beta = 0.146$, $p = 0.000$). Support for H_9 is therefore provided.

The other two hypotheses of perceived climate change effects (H_{10} and H_{11}), which state that perceived climate change effect has negative and significant relationship with sustainable maize production practices and food security of the maize-farming households were found not to have significant relationships ($\beta = 0.019$, $p = 0.624$; and $\beta = 0.026$, $p = 0.375$ respectively). Contrary to the expected sign of perceived climate change effect having negative relationship with the sustainable maize practices, the result reveals otherwise. It was envisaged that as farmers are faced with the negative impact of climate change in so many aspects of their farming businesses, they will be adopting agronomic practices that might be inimical to sustainability of the production system in the area. However, the result indicated that those who felt the effect of climate change impact are rather more likely to practise sustainable agriculture. Since the result is not significant and the marginal effect is very negligible, one needs to be cautious in holding the relationship between these two latent variables. Though the relationship of perceived climate change effects with food security was not significant, the expect sign was consistent. This is indicative of the fact that those farming households who face a lot of impact from the climate change effect tend to be more food insecure than those who lower form of the climatic effects. Again, since the result is not significant, it will be very difficult to make such statements without caution. These two hypotheses, H_{10} and H_{11}, were therefore not supported by the findings of the current study.

In hypothesis 12, the researcher posited that livelihood diversification has a positive relationship with effective climate change responses. Consistent with the initial expectation livelihood diversification was found to have a significant positive relation with climate change responses ($\beta = 0.141$, $p = 0.000$). The positive relationship implies that an improvement in livelihood diversification would possibly translate to an improvement in climate change responses. In other words, those farming households who plant more than one variety of maize or different crops, or are involve in different kinds of income generation activities tend to adapt to climate change effects more. Support for hypothesis 12 was therefore provided for this research. This also supports other studies by Deressa et al. (2009), Sofoluwe et al. (2011), Tazeze et al.(2012) and Obayelu et al. (2014) that having positive returns from alternative livelihood income generation activities leads to higher investment in adaptation options for farmers.

In hypothesis 13 the researcher put forward positive and significant relationship between livelihood diversification and attitudes towards sustainable agriculture. Consistent with the initial expectation livelihood diversification was found to have a significant positive relation with attitudes towards sustainable agriculture ($\beta = 0.135$, $p = 0.000$). The positive relationship indicates that those farming households who have diversified livelihood activities tend to have positive attitudes towards sustainable agriculture. This hypothesis is therefore supported with the findings of the study.

Contrary to the proposed hypothesis H_{14} that livelihood diversification significantly increase sustainable production practices, the relationships was not significant ($\beta = 0.013$, $p = 0.695$). This implies that ability of maize-farming households to diversify their livelihoods does not significantly influence their practices of sustainable maize production. Though the relationship was positive, the coefficient (β) was however too small for the relationships to be significant. The hypothesized effects were therefore not supported. Pretty and Bharucha (2014) reported ability of farmers to increase food outputs by sustainable intensification in two ways. The first is multiplicative whereby yields per hectare have increased by combining use of new and improved varieties with changes to agronomic and agro-ecological management. The second is improved food outputs through additive means in which diversification of farms resulted in the emergence of a range of new crops, livestock or fish that added to the existing crops already being cultivated.

In hypothesis 15 (H_{15}) the study also proposed that livelihood diversification of maize-farming households increase their food security levels. Consistent with the earlier position, livelihood diversification was found to be a negative predictor of food security index ($\beta = -0.180$, $p = 0.000$). The result implies that maize-farming households will improve their food security levels if they venture into the production of different crops and varieties, or engage in different income generation activities. The hypothesis is therefore supported. Diversification as increase in the number of income generating activities will enable the farmers to have more resources that could be used to avert food shortage. As Abimbola and Oluwakemi (2015) puts it, one of the reasons why farmers diversify is to increase income from alternative livelihoods sources. Babatunde (2013) also posited that farming as a primary income sources has failed to guarantee sufficient livelihoods for most households. Hence, the need to look for supplementary sources of livelihood improvement. Belaineh (2002) also buttress the fact that diversification is important feature of survival in rural households. Reta and Ali (2012) reiterated that if there had not been other sources of income apart from agricultural production, feeding households members cannot be fulfil. Yenesew et al. (2015) also opined that livelihood diversification is believed to be a solution to food security. All these point to the fact that livelihood diversification holds very important place in attaining food security among the maize-farming households in the Volta Region.

Hypothesis 16 posited positive and significant relationship between farmers' attitudes towards sustainable agriculture and climate change response strategies adopted to reduce climate change effects. The finding reveals that, consistent with the expectation, the relationship between attitudes and climate change response strategies was found to be positive and significant (β=0.148, p = 0.000). The result implies that farmers who have high positive attitudes towards sustainable agriculture will also use enhanced strategies to avert climate change effect on their Maize farming business. The hypothesis is therefore supported.

In hypothesis 17 the study proposed that, farmers' attitudes towards sustainable agriculture has significant and positive relationship with their sustainable production practices. Consistent with the initial position of this study, farmers attitudes toward sustainable agriculture was found to have a positive and relationship with sustainable agricultural practices (β = 0.465, p = 0.000). The proposition of the study is therefore supported. This result from the SEM also validates the results in Table 36 (effects of farmers attitudes towards sustainable production of maize farmers in Volta Region), which presented the various indicators of attitudes and how they influence sustainable production practices among maize farmers.

Hypothesis 18 proposed a negative and significant relationship between attitudes toward sustainable agriculture and food security index. From Table 59 it can be seen that the relationship is significant and inversely related (β = -0.236, p = 0.000). This is an indication that those farming households who have positive attitudes towards sustainable agriculture, tend to reduce their food insecurity levels. The result implies that an improvement in the attitudes towards sustainable agriculture is expected to improve food security situation of the farming households. This also alludes to the fact that those who are food insecure tend to think more of getting food to avert the situation rather than thinking about sustainability of the production system. Thus, when individuals are hungry, the first and foremost concern is to satisfy such a need before any other needs be met. The basic needs such as food, shelter and clothing must be met before thinking of any other thing.

In Hypothesis 19, climate change response was anticipated to have a positive relationship with sustainable agricultural practices. Consistent with the earlier position, climate change responses was found to be a positive predictor of sustainable agricultural practices. This was significant at 0.01 alpha level (β = 0.130, p = 0.001). The result implies that there will be improvement in sustainable agriculture practices if maize-farming households adopt diverse strategies to help them out of the negative climate change effects. The hypothesis is therefore supported.

In hypothesis 20 the study also proposed that climate change responses by of maize-farming households improve their food security levels. Consistent with the earlier position, climate change responses was found to be a negative predictor of food security index (β = -0.388, p = 0.000). The result implies that maize-farming households will improve their food security levels if they adopt strategies that will reduce climate change effect on their production activities. The hypothesis is therefore supported.

The last hypothesis (H_{21}) posited a negative relationship between sustainable agricultural practices and food security index. As stated, sustainable production practice was found to have a negative relation with food insecurity levels. However, this relationship was not to significant (β = -0.033, p = 0.284). The implication is that having practicing sustainable production may not necessarily have any significant effect on food security levels of the farming households. This hypothesis is therefore not supported. (Elliot, Firbank, Drake, Cao and Gooday (2013) explored outcomes of sustainable intensification and reported that sustainability can be achieved through a mixture of new technologies (improved genetics and precision farming), new practices (zero-tillage and improved water management), diversification (the installation of small-scale energy generation) and the application of available agri-environmental schemes.

Evaluating the Coefficient of Determination, R^2

The coefficient of determination (R^2) is a measure of the variance in each endogenous construct that is explained by the model or simply the predictive power model (Chin, 2010; Sarstedt et al., 2014). R^2 values range from 0 to 1 (or 0 % to 100%), in absolute terms, with values closer to 1 or 100 percent indicating a greater degree of predictive power. For the predictive power of an endogenous variable to have practical and statistical significance, it is recommended that R^2 values should be ≥ 0.10 (Lee, Petter, Fayard, & Robinson, 2011). An R^2 value of 0.670, 0.33 or 0.19 represents substantial, moderate and weak predictive power respectively.

From Table 60, R^2 for the food security levels was 0.531, representing moderate predictive power. The result implies that more than 53 percent of the variation in food security is accounted for by the proposed variables predicting it.

These variables predicting food security in the structural model include climate change response strategies, production sustainability, livelihood diversification, climate change effects and attitudes towards sustainable agriculture.

The R^2 values (Original Sample [O] column) for sustainable production practices and climate change responses were 0.349 and 0.381 respectively, indicating moderate predictive power. The R^2 for farmers' attitudes towards sustainable agriculture was 0.145, indicating significant but weak predictive power. Livelihood diversification also has significant but weak predictive power of 7 percent. The results support the statements by Chaudhari, Rajkumar, and Shreedhara (2018) that adaptation strategies seem to be the most immediate needs to save livelihoods and ensure food security.

Table 60: Coefficient of determination of endogenous variables

Endogenous Variables	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistics (|O/STDEV|)	P-Values
PCCE	0.001	0.002	0.003	0.303	0.762
ASA	0.145	0.150	0.023	6.321	0.000
LivDiv	0.070	0.074	0.019	3.686	0.000
CCR	0.381	0.386	0.031	12.310	0.000
SUSAG	0.349	0.355	0.027	12.816	0.000
FSI	0.531	0.535	0.020	27.080	0.000

Source: Field survey, Akaba (2018)

Evaluating Predict Relevance, Stone-Geiser Q^2

The researcher employed the Stone Geiser $Q^{2'}$ to assess the predictive relevance of the proposed model. The Stone-Geiser Q^2 is a measure of how accurately the model predicts observed data points. The values of Q^2 were obtained using the blindfolding technique. Stone-Geiser Q^2 value larger than 0 gives indicative of predictive relevance. From Table 61, the proposed model reports Q^2 of 0.071, 0.041, 0.222, 0.244 and 0.336 for attitudes towards sustainable agriculture, livelihood diversification, climate change responses, sustainable agricultural practices and food security respectively. That of perceived climate change effect was zero, which is an indication of no relevance in predicting climate change effects using the constraining factors. However, since the rest of the latent variables have Q^2 above zero, it indicates that the proposed model has predictive relevance.

Table 61: Predictive Relevance of Endogenous Variables

	SSO	SSE	Q^2 (=1-SSE/SSO)
CONST	1,466.000	1,466.000	
PCCE	1,466.000	1,465.641	0.000
ASA	8,796.000	8,175.619	0.071
LivDiv	2,199.000	2,109.408	0.041
CCR	5,864.000	4,564.319	0.222
SUSAG	2,199.000	1,662.603	0.244
FSI	2,199.000	1,459.683	0.336

Source: Field survey, Akaba (2018)

The value from the structural model evaluation can also be computed through the Q^2 predictive relevance, often called predictive sample reuse (Geisser, 1974; Stone, 1974). This technique can represent the synthesis from the cross-validation function and function fitting which is between the observed variable prediction and parameter construct estimation. This approach was done with the blindfold procedure (Latan & Ramli, 2013). If $Q^2 > 0$, it shows that the model has predictive relevance, but if $Q^2 < 0$, it explains that the model has less predictive relevance. The Q^2 predictive relevance of 0.02, 0.15 and 0.35 signify a weak, moderate and strong mode respectively. Deducing from this assertions, it could be said that food security index, sustainable agricultural practices and climate change responses have moderate predictive relevance (Q^2 = 0.336, 0.244 and 0.222 respectively), while attitudes towards sustainable agriculture and livelihood diversification have weak predictive relevance ($Q^2 = 0.071$ and 0.041 respectively).

Model Fit

The SmartPLS3 analysis provides a number of fit indices for evaluating the fitness of the estimated model. The overall model fit was assessed using the standardized root mean square residual (SRMR) composite factor model (Henseler et al., 2014). According to Hu and Bentler (1999), SRMR values less than 0.08 indicate a good model fit. As presented in Table 62, the SRMR for the estimated model was 0.078. This value is slightly below the recommended threshold, indicating good model fit.

Table 62: Model Fit Indices

Fit index	Estimate	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistics (|O/STDEV|)	p-Values
SRMR	0.078	0.032	0.001	65.581	0.000
d_ULS	3.384	0.571	0.043	79.497	0.000
d_G1	1.245	0.444	0.027	45.675	0.000
d_G2	0.880	0.325	0.012	73.832	0.000

Source: Field survey, Akaba (2018)

Besides the use of SRMR, Dijkstra and Henseler (2015) indicated that d_ULS and d_G values must be significant to indicate good model fit. The results from Table 62 are all having p-values well below the alpha levels of 0.05. From the results it can be concluded that all the model fit indices used to evaluate the fitness of the estimated model show that the estimated model exhibits good model fit.

PLS Multi-Group Analysis (Geographic Zone Differences)

The partial least square multigroup analysis (PLS-MGA) was used to test the geographical zone differences in path coefficients and R^2 using SmartPLS3 (Table 63). Comparing groups of respondents is important from the practical and theoretical perspective. The Welch-Satterthwaite test of difference was performed to see if the path coefficient of the model using only Northern zone data was significantly different from the model using either only Middle zone or only Southern zone data. The same process was then repeated for the difference between Middle zone and Southern zone. From the result presented in Table 63 it can be seen that there is no difference between Northern Volta (NV) and Middle Volta (MV) for two-thirds of the paths except the ASA → SUSAG, CCR → SUSAG, CONST → CCR, LivDiv → FSI, PCCE → ASA, PCCE → FSI, and PCCE → LivDiv paths (p-values for difference is less than 0.05). For the Welch-Satterthwaite test of difference between NV and Southern Volta (SV), eleven (11) paths were seen to be significantly different. These paths were ASA → CCR, ASA → SUSAG, CCR → FSI, CONST → ASA, and CONST → CCR, CONST → FSI, CONST → LivDiv, CONST → PCCE, LivDiv → SUSAG, PCCE → CCR AND PCCE → LivDiv. Similarly, the Welch-Satterthwaite test of difference between MV and SV showed 11 significant differences. These were CONST → SUSAG, LivDiv → CCR, CCR → FSI, CONST → ASA, and LivDiv → FSI, CONST → FSI, CONST → LivDiv, CONST → PCCE, LivDiv → SUSAG, PCCE → CCR and PCCE → ASA paths. Based on the result one can comfortably say that geographical locations have some level of moderating effect on our model.

Table 63: Welch-Satterthwait Test of Difference in path Coefficients

	NV-MV					NV-SV					MV-SV				
	R Squares					R Squares					R Squares				
Hypothesized Path	MV	NV	diff.	t-Value	p-Value	NV	SV	diff.	t-Value	p-Value	MV	SV	diff.	t-Value	p-Value
ASA -> CCR	0.200	0.245	0.045	0.571	0.568	0.245	0.045	0.199	2.624	0.009	0.200	0.045	0.155	1.781	0.076
ASA -> FSI	-0.205	-0.307	0.102	1.480	0.140	-0.307	-0.163	0.144	1.956	0.052	-0.205	-0.163	0.042	0.587	0.558
ASA -> SUSAG	0.374	0.578	0.204	2.565	0.011	0.578	0.364	0.214	2.791	0.006	0.374	0.364	0.010	0.131	0.896
CCR -> FSI	-0.298	-0.235	0.063	0.892	0.373	-0.235	-0.645	0.411	5.997	0.000	-0.298	-0.645	0.348	5.313	0.000
CCR -> SUSAG	0.241	0.043	0.197	2.105	0.036	0.043	0.067	0.024	0.228	0.820	0.241	0.067	0.174	1.556	0.121
CONST -> ASA	-0.318	-0.431	0.112	1.374	0.171	-0.431	-0.109	0.322	3.622	0.000	-0.318	-0.109	0.209	2.333	0.020
CONST -> CCR	-0.036	-0.333	0.298	3.757	0.000	-0.333	-0.062	0.271	3.586	0.000	-0.036	-0.062	0.026	0.323	0.7
CONST -> FSI	0.340	0.340	0.001	0.008	0.994	0.340	0.093	0.2	3.512	0.001	0.340	0.093	0.248	3.490	0.001
CONST -> LivDiv	-0.341	-0.386	0.045	0.550	0.583	-0.386	0.026	0.412	4.529	0.000	-0.341	0.026	0.367	3.870	0.000
CONST -> PCCE	-0.202	-0.311	0.108	1.401	0.163	-0.311	0.225	0.535	6.538	0.000	-0.202	0.225	0.427	5.244	0.000
CONST -> SUSAG	-0.052	-0.153	0.101	1.245	0.214	-0.153	-0.285	0.132	1.299	0.195	-0.052	-0.285	0.232	2.190	0.030
LivDiv -> ASA	0.137	0.164	0.028	0.294	0.769	0.164	0.076	0.088	0.930	0.353	0.137	0.076	0.061	0.599	0.550
LivDiv -> CCR	0.208	0.103	0.105	1.350	0.178	0.103	0.013	0.090	1.252	0.212	0.208	0.013	0.195	2.452	0.015
LivDiv -> FSI	-0.273	-0.107	0.166	2.706	0.007	-0.107	-0.089	0.017	0.283	0.777	-0.273	-0.089	0.183	2.785	0.006
LivDiv -> SUSAG	0.088	0.111	0.023	0.295	0.769	0.111	-0.118	0.229	2.869	0.004	0.088	-0.118	0.205	2.306	0.022
PCCE -> ASA	-0.233	0.120	0.353	4.195	0.000	0.120	0.236	0.116	1.350	0.178	-0.233	0.236	0.469	5.420	0.000
PCCE -> CCR	0.445	0.339	0.105	1.290	0.198	0.339	0.610	0.271	3.602	0.000	0.445	0.610	0.166	2.086	0.038
PCCE -> FSI	0.112	-0.049	0.161	2.484	0.014	-0.049	0.036	0.085	1.140	0.255	0.112	0.036	0.076	0.985	0.326
PCCE -> LivDiv	0.174	-0.043	0.217	2.434	0.016	-0.043	0.238	0.281	3.174	0.002	0.174	0.238	0.064	0.700	0.484
PCCE -> SUSAG	-0.0	0.019	0.066	0.888	0.375	0.019	-0.003	0.021	0.230	0.818	-0.0	-0.003	0.044	0.440	0.661
SUSAG -> FSI	-0.051	-0.040	0.012	0.163	0.871	-0.040	0.001	0.040	0.535	0.593	-0.051	0.001	0.052	0.654	0.513

Source: Field survey, Akaba (2018)

Further, a test of difference among the geographical zones in R^2 for all endogenous variables in the model was performed. Results from Table 64 between Northern zone and Middle zone show that there were significant differences in R^2 for sustainable agricultural practices, climate change responses, food security and attitudes towards sustainable agriculture. There was however, no difference in R^2 for livelihood diversification and perceived climate change effects. Similarly, the results between Northern zone and Southern zone show that there were significant differences in R^2 for sustainable agricultural practices, climate change responses, food security and attitudes towards sustainable agriculture. There was however, no difference in R^2 for livelihood diversification and perceived climate change effects.

The results between Middle and Southern zones reveal that there were significant differences in R^2 for only livelihood diversification and food security. On the other hand, there were no significant differences in R^2 for sustainable agricultural practices, climate change responses, attitudes towards sustainable agriculture and perceived climate change effects. These revelations show clear evidence of moderating effects of the geographical location on the models.

Table 64: Welch-Satterthwaite test of difference in R^2

Northern zone versus Middle zone					
Endogenous Variable	R Squares				
	MV	NV	diff.	t-Value	p-Value
ASA	0.162	0.315	0.153	2.572	0.011
CCR	0.336	0.545	0.209	3.129	0.002
FSI	0.591	0.708	0.117	2.7	0.006
LivDiv	0.170	0.140	0.030	0.504	0.615
PCCE	0.041	0.096	0.056	1.355	0.177
SUSAG	0.287	0.568	0.281	4.052	0.000
Northern zone versus Southern zone					
	R Squares				
	NV	SV	diff.	t-Value	p-Value
ASA	0.315	0.069	0.246	4.315	0.000
CCR	0.545	0.378	0.167	2.436	0.016
FSI	0.708	0.483	0.225	5.691	0.000
LivDiv	0.140	0.060	0.080	1.568	0.118
PCCE	0.096	0.051	0.046	1.040	0.299
SUSAG	0.568	0.240	0.328	4.837	0.000
Middle zone versus Southern zone					
	R Squares				
	MV	SV	diff.	t-Value	p-Value
ASA	0.162	0.069	0.092	1.787	0.075
CCR	0.336	0.378	0.042	0.588	0.557
FSI	0.591	0.483	0.108	2.098	0.037
LivDiv	0.170	0.060	0.110	2.037	0.043
PCCE	0.041	0.051	0.010	0.272	0.786
SUSAG	0.287	0.240	0.0	0.681	0.496

Source: Field survey, Akaba (2018)

Importance-Performance Matrix Analysis

The importance-performance map analysis (IPMA; also called importance-performance matrix, impact-performance map, or priority map analysis), is a useful analysis approach in PLS-SEM that extends the standard results reporting of path coefficient estimates by adding a dimension that considers the average values of the latent variable scores. The goal is to identify predecessors that have a relatively high importance for the target construct (i.e. those that have a strong total effect), but also have a relatively low performance (i.e. low average latent variable scores) (Ringle & Sarstedt, 2016). A standard PLS analysis provides information on the relative importance of constructs in predicting other constructs. IPMA however, extend the stand PLS results by taking into account the performance of each construct. Useful policy implications could be drawn from an IPMA analysis. For example, development agencies would have to prioritize action on improving performance in variables that, simultaneously, have a relatively low performance. Resources that are concentrated on variables that are less important could be channeled to other areas that are more important. Figure 8 presents the results of the IPMA analysis with seven (7) construct variables which are constraints to maize production (CONST), perceived climate change effects (PCCE), livelihood diversification (LivDiv), attitude towards sustainable agriculture (ASA), responses to climate change effects (CCR), sustainable agricultural practices (SUSAG) and food security index (FSI). In this PLS path model, FSI represents the final target variable, which is directly predicted by CONST, PCCE, LivDiv, ASA, CCR and SUSAG. Furthermore, CONST has indirect effect on FSI through LivDiv, PCCE, ASA, CCR and SUSAG. Similarly, PCCE has indirect effect on FSI through LivDiv, ASA, CCR and SUSAG. Further, LivDiv has indirect effect on FSI through ASA, CCR and SUSAG. More so, ASA has indirect effect on FSI through CCR and SUSAG. Finally, CCR has indirect effect on FSI through SUSAG. Adding the predecessor constructs direct and indirect effects results in their total effects on FSI, which represents the importance dimension in the IPMA. The average latent variable scores of the constructs indicating their performance whereby high values indicate a greater performance (Ringle & Sarstedt, 2016).

The first most important construct in the path model for the target latent construct is climate change responses (CCR). All things being equal, a unit increase in in the number of climate change response strategies adopted by the maize farmers will lead to about a double (1.965) reduction in the food insecurity levels. However, CCR has the second lowest performance (50.738) among all the predecessors constructs. Improving adaptive capacities of maize-farming households towards climate change shocks will consequently improve their food security situations.

The second most important construct in the path model for the target latent construct (FSI) is the livelihood diversification of maize-farming households (LivDiv). All things being equal, a unit change in livelihood diversification will lead to a 0.323 increase in the food security levels. On the other hand, livelihood diversification has the lowest performance (38.856) among all the predecessors constructs. Alternative income generation activities and/or increase in the use of a number of varieties of maize for production and/or engaging in different types of crop production is therefore suggested to improve food security levels of the Maize farming households.

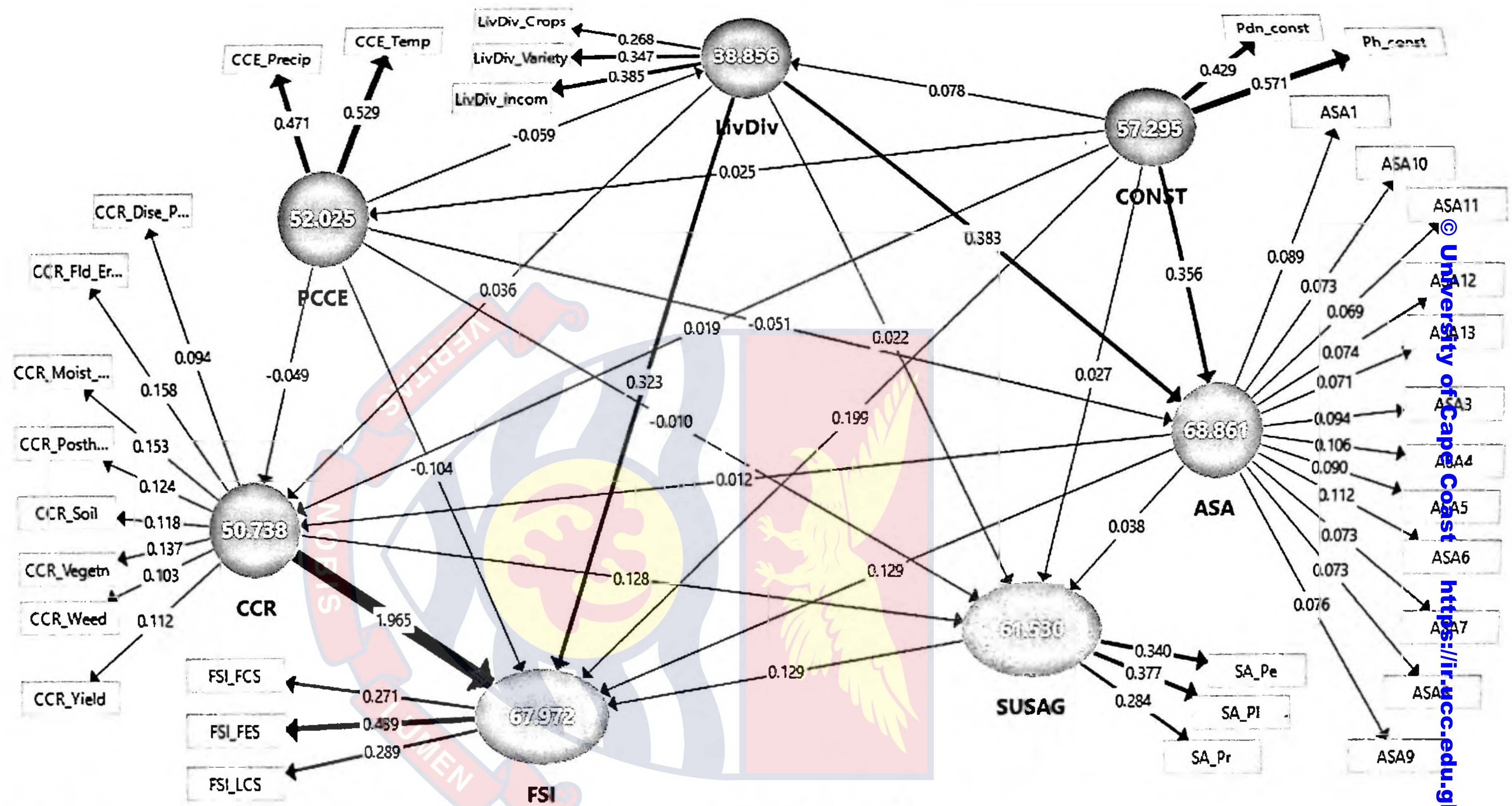

Figure 8: Importance performance map analysis for the constructs in the SEM

Source: Field survey, Akaba (2018)

The third most important predecessor construct in the path models is the constraints to maize production. Thus an increase in the efforts to reduce the number of production and postharvest constraints in maize production will lead to improvement in the food security levels of the Maize farming households. Attitudes towards and practices of sustainable agriculture have similar effects on food security (0.13) while the latent construct that has the lowest effect on level of food security was the PCCE. Although attitudes and practices of sustainable agricultural production have comparable levels of importance, ASA has a considerable higher performance than the SUSAG construct. Efforts towards changing attitudes towards sustainable agriculture should therefore be given a priority if these two constructs are to be considered, all things being equal.

Summary

This last empirical chapter was dedicated to developing models for improving adaptive capacity in the face of climate change shocks, food security and production sustainability among the maize-farming households in the Volta Region. The model estimation was conducted using the partial least square structural equation modelling approach, which enable the study to analyse both the measurement and structural models. Measurement models were assessed using reliability, convergent validity and discriminant validity. Based on the structural path coefficients, twenty-one (21) different hypotheses were tested. In addition, the predictive power and predictive relevance were assessed using coefficient of determination and Stone-Geiser Q^2 respectively. Model fit indices employed in the testing for the quality of estimations include SRMR composite factor model, the Geodesic Discrepancy (d_G), the Unweighted Least Squares Discrepancy (d_ULS), the average R-squared, the average path coefficient and the Tenenhaus Goodness of Fit index (GoF). Lastly an Importance-Performance Matrix Analysis (IPMA) was performed to determine the relative importance of the factors that explained each of the endogenous variables in the structural model.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

Agriculture is one of the most vulnerable sectors to climate change impacts. At the same time, agricultural production systems pose negative impacts on the ecosystems. Multiple factors, including a changing climate, are contributing to the myriad socio-ecological crises of farm enterprises. Farming in the Anthropocene requires farmers to be more responsive to climate change and sustainability. Sustainable agricultural approaches are emerging as a new paradigm for adapting agriculture to the changing climate and at the same time achieve food security for households. This approach seeks solutions that improve agricultural productivity, build resilient food production systems, and improve environment.

Climate change is a complex and crosscutting problem that needs an integrated and transformative systems approach to respond to the challenge. Current sectoral approaches to climate change adaptation initiatives often create imbalances and retard sustainable development. Sustainable agriculture is increasingly recognized as important strategy for climate change adaptation. Climate change and sustainable agricultural production have been a subject of vigorous debate, research, and experimentation. Production sustainability includes environmental protection, social justice, and improved livelihoods, all of which can be achieved by following better farm-management practices that can reduce the negative influence of climate change.

To meet the food demands of the exponentially increasing population, a massive food production is necessary. Agricultural practices must be sustained by the ability of farmers to produce food to satisfy their household needs indefinitely as well as having sustainable impacts on the broader environment. Sustainable agriculture must be inclusive and have adaptability and flexibility over time and geographical space to respond to the demands for food and livelihoods. This study addressed and gave insights in generating awareness of climate change responses, food security and the perspectives of sustainable food production towards human society.

Like other farmers, maize farmers in the Volta Region face traditional challenges, such as maintaining soil fertility, water supply, and control of pests and disease. All of these issues and more are aggravated by climate change. Farmers have been making efforts to adapt to climate change, to make their farms resilient and productive. However, some of these efforts rather compound the problems due to the fact that they contribute negatively to sustainability. The study adapted contemporary advancement in data analysis by employing structural equation modelling in pointing out strategies farmers used to achieve food security and increase their adaptive capacity to climate change and at the same time achieving sustainable agriculture.

Summary

Climate change is expected to have serious environmental, economic, and social impacts on farming households, particularly on maize farmers whose livelihoods depend largely on rainfall. Despite its high contribution to the overall economy, the agricultural sector is challenged by many factors especially climate-related disasters like drought, erratic rains, floods, strong winds and high temperatures. In recent years, adaptation to climate change has become a major concern to maize farmers, researchers and policy makers alike. To enhance efforts towards confronting the challenges posed by climate change to maize farmers, it is important to know the implication of maize farmers' perception and response strategies to climate change effects on production in the Volta Region of Ghana. The Volta Region is situated in the eastern part of Ghana and stretches from the south to the north, hence having almost all the agro-ecological and socio-demographic features of the country. To continue high food production in this region, maize farmers would have to adapt to climate change related stresses. Their response strategies could have implications for the sustainability of the agricultural production systems, and food and livelihood security.

Four empirical chapters were covered in this study. The first presented and discussed results on the state of maize production sustainability among farming households in the Volta Region. This was accomplished by delving into farm- and farmer-specific backgrounds of the maize production enterprises in the Volta Region. It also covered livelihood diversifications and constraints to maize production among the Maize farming households. The analysis provided the insight into the extent and predictors of livelihood diversification among maize farmers in the region utilising cross-sectional estimation procedures. The Garrett ranking techniques' was also used to identify and rank the constraining factors to maize production enterprises.

This first empirical chapter also employed both multiple linear regression models to estimate and investigate the causal relationships with attitudes and practices of sustainable agricultural production. It evaluated the attitudes of the farmers using the interval of standard deviation from the mean approach. The Kendall's Coefficient of Concordance was also used to estimate the level of agreements among the farmers on the relative importance of indicators used to measure sustainable agriculture. Pearson Product Moment Correlation was conducted to measure the associations between farmers' attitudes and selected farm- and farmer-specific characteristics. It further went on to estimate significant predictors of attitudes of farmers towards sustainable agriculture using multiple linear regression models. A one-way ANOVA was also run to show differences across the geographical zones in the region. Another linear regression was conducted to show how attitudes of farmers towards sustainable agriculture influence their sustainable production practices. A Friedman test was conducted to show significant differences among the various dimensions of sustainability.

The second empirical chapter provided results and discussions on the contribution of maize production enterprises to food security in the Volta Region of Ghana. The prevalence of food insecurity was estimated using the consolidated approach to reporting indicators of food security (CARI). Three main domains used in the food security index estimation were the food consumption score, food expenditure share and the livelihood-based coping strategies. Friedman test was conducted to find out differences in the levels of food security within the various components used for the food security index. Besides, analysis of variance was also used to show differences in food security levels across the region. A logistic regression was also conducted to estimate the maize production enterprise characteristics that contribute to food security.

The third empirical chapter examined response strategies maize farmers adopted to increase their resilience to the negative effects of climate change in the Volta Region. This was preceded by evaluating their perceptions on climate change and how it has affected their production enterprises. Analysis of variance was applied in divulging the differences across the geographical zones of the region.

The last empirical chapter was on the model development to estimate the pattern and interrelationships among the key variables of the study (food security, sustainable agricultural practices, attitudes towards sustainable agriculture, climate change effects and responses, livelihood diversification, and constraints to Maize farming enterprises). The structural equation modelling with partial least square was used to estimate the causal relationships among these variables. Data quality criteria were conducted using several methods including Kolmogorov-Smirnov, Shapiro-Wilk to test for the non-normality assumption and appropriateness of using the SEM. The reliability of the latent variables were also tested using the Cronbach's alpha (α), Dijkstra-Henseler's rho (ρA), and Dillon-Goldstein's rho (ρc). Average Variance Extracted (AVE) was used to measure the convergent validity of the latent variables while Fornell-Larker and Heterotrait-Monotrait (HTMT) criteria were also used to measure discriminant validity. The assessment of the structural model was based on the sign, magnitude and significance of path coefficients of each hypothesized path. In order to determine the significance of each estimated path, the bootstrapping procedure was used with 5000 resamples drawn with replacement. The predictive power together with the predictive relevance of the estimated models was assessed using the Coefficient of determination and the Stone-Geiser Q^2 respectively. Model Fit indices such as the Standardized Root Mean Square Residual (SRMR) composite factor model, the Geodesic Discrepancy (d_G), the Unweighted Least Squares Discrepancy (d_ULS), the average R-squared, the average path coefficient and the Tenenhaus Goodness of Fit index (GoF) were also used to assess the fitness of the estimated model. Lastly an Importance-Performance Matrix Analysis (IPMA) was performed to determine the relative importance of the factors that explained each of the endogenous variables in the structural model.

State of maize production sustainability in the Volta Region

The production of maize in the Volta Region could typically be described as predominantly male dominated with majority being the youth who were either cohabitating or legally married. The levels of education of these farmers could generally be described as either basic or secondary education with an average age of 9 years in formal education. Never-the-less, the farmers had relatively substantial number of years of experience in the production of their staple food in question (maize). The household size of these maize-farming households could generally be described as large, where those in the northern zones haver significantly larger household sizes than those from the south.

Most of the farmers either used monocropping or mixed cropping for the production of maize in the region with the aim of achieving food security or serving as income generating activities. Land holdings in maize production is characterised by small sizes which are either owned or inherited from families. Though farming was the main livelihood activity for most of the Maize farming households, a substantial number of them were engaged in other income generating businesses including non-farm and off-farm livelihoods strategies.

It was evident for the study that majority of the farmers produce different types of maize varieties and at multiple locations to avert the negative effects of climate variability and other consequential outcomes such as diseases and pests outbreak, severe droughts, and flooding. The most significant varieties that farmers relied on to achieve these aims include Obatampa, Local, Dzinueve, Proceed and Mamaba. Other varieties planted include Pana, Dorke, Etubi, Duati, and Abelehee. Some of these varieties are early maturing, high yielding, drought tolerant, and/or disease resistant. Farmers therefore combine these varieties to serve more as a coping strategy so that in case there is a particular unfavourable condition, even if they lost the variety that is susceptible to that condition, they could derive yield from the rest of the locations. This is to enable them achieve food security and generate some level of income. In addition to planting multiple varieties, farmers also produce other crops in tandem with the maize farming. Some of the major crops produced in addition to maize include vegetables; other cereals like rice, root and tubers such as yam, cassava and potatoes; legumes; and plantation crops like plantain, banana, cocoa and oil palm.

There were significant differences among the geographical zones regarding their livelihood diversifications, where those farmers from the Northern Volta had significantly lower levels of diversification than their Middle and Southern counterparts. This could be concluded that since most of the alternative livelihood activities abound more in the south than the north, maize-farming households in the south tend to take advantage of these opportunities to augment their livelihoods. This revelation could also be as a result of the south having more development facilities more than the north; hence the maize farmers from the north could not get access to these development facilities that will enable them to venture into alternative livelihood activities that can generate more income for them. Thus any shocks from the farming as a result of external factors such as bad weather, pest outbreaks and crop failure could have negative repercussions on the maize-farming households in the northern part of the region.

Most farmers tend to have farming as their main occupations due to their inability to pursue formal education. Farmers who are engaged in other livelihood activities as their main occupation were more productive in maize production than those farmers who are fully into farming as their main business. Besides, older farmers tend to rely on farming as their main occupation than their younger counterparts. Since their main occupation is farming, these farmers tend to produce maize on a monocrop basis and also have access to extension services more than those who have other works as their main business.

Farm- and farmer-specific factors which tend to significantly influence alternative income generation activities were years in formal education, household size, land productivity, Maize farming experience use of improved maize seeds and land tenure security. The main determinants of crop diversifications were size of farm holding, number of plots in different locations, household size and age of the farmer. These factors tend to positively influence crop diversification.

Factors constraining Maize farming enterprise in the Volta Region

In their efforts to achieving the objectives of maize production, farmers are faced with myriads of challenges. Some of these are geographical specific while others cut across the whole region. For instance, undercapitalization, low yield, high cost of inputs and difficulty in accessing credit for maize production, which are main constraints ranked by the maize farmers tend to cut across the region. However, difficulty in controlling weed tends to be a major problem only in the Northern Volta, while difficulty in accessing labour seems to be a major problem in the Middle Volta. Besides, disease outbreak and its associated problems tend to be more prominent and devastating in the Southern Volta than other parts of the region. On the other hand, the postharvest constraining factors showed that uncertain demand and high postharvest losses tend to cut across the region while unremunerated prices and high transportation costs tend to be problems associated with the Southern Volta and Middle Volta respectively.

Contribution of Maize farming to food security

Majority of the maize-farming households were food insecure. About 50 percent of them were vulnerable to become food insecure or were moderately food insecure. The indicators used for the measuring food security (FCS, FES and LCS) had different levels of food security among the respondents.

Food security estimates are highly influenced by the type of indicators used in measuring the levels and geographical locations of individual households. Depending on the domain used, food security levels could be affected by the kind of approach adopted in measuring household food security. Male respondent households were significantly more food secure than their female counterparts. Though married respondents households had better levels of food security than those who were single, these differences could generally be described as statistically not significant.

The computed odds ratio of the study indicates that higher education, large farm holdings, row planting, access to extension services and land productivity increase the probability of food security while farming as main occupation and paying for land for Maize farming decrease the probability of food security.

Climate change responses

Climate change is a threat not just to maize-farming households but every farmer. The corollaries of climate change unsettle economies and affect livelihoods of Maize farming households. Some of these outcomes include extreme weather events, and reduced crop yield. These types of scenarios were illustrated in the various examples of drought-stricken regions in the Volta Region, where people were forced to adapt through crop switching or novel irrigation techniques. Extreme climatic conditions and their variability with time play an important role in the crop production and overall yield.

Maize farmers stated that they are currently experiencing extremely high temperatures, which were not happening in the past. Most of them also indicated changes in precipitation and high variability in rainfall patterns. Majority also reported frequent droughts and protracted dry spells which could occur even during mid-seasons. They indicated that these have not be so in the past but in recent years the climate variability is rendering them not to be able to effectively plan for their farming activities. Their inability to forecast for their farming activities is limiting their adaptive capacity and increasing their vulnerability to the changes in climate and food insecurity.

The maize production systems of the farming households in the study area could be said to be under stress due to poor and unpredictable climatic conditions. Climatic conditions in the region are seen to have high variability in both temporal and spatial distribution of rainfall causing a corresponding high variability in droughts and flood. Maize-farming households are highly vulnerable because their production systems are largely rain-fed. Though agricultural production may have the potential to improve food security, climate change could inhibit such progress in the long run, given the sector's vulnerability. The extreme droughts or prolonged dry spells, coupled with high temperature have prompted most farmers to adopt adaptation strategies, some of which are likely to have adverse impacts on sustainability of the farming business activities.

Maize farmers using response strategies could also be described as both adaption and mitigation strategies. The adaptation strategies could also be said to be both preventive adaptation, which predicts and responds to vulnerabilities before damages are incurred, and reactive adaptation, that gears up to limit the recurrence of damage only after effects of climate change have been felt and damage done, in order to limit recurrence of the damage. For instance, farmers have resorted to the planting of high yielding and short duration or early maturing crops, which they believe could be harvested in real time before the adverse impact of extreme weather set in. Some of them were also forced to adapt through crop switching or novel livelihood diversification strategies.

While farmers suffer at the expense of climate change, they are also the perpetrators. Greenhouse gas emissions from farming activities are driving the effects of climate change, including changing weather patterns, extreme weather events, prolong droughts, flooding, and adverse winds. Nonetheless, some of the mitigation and adaptation efforts can change the spiral of events; though, successful implementation depends on sustainable measures, relevant tools, effective governance and policy measures, and an enhanced capacity of farmers to respond on sustainable bases.

Sustainable production practices in the Volta Region

While those maize farmers from the Middle and Northern Volta have high levels of attitudes toward sustainable agriculture, those from the Southern Volta had low levels of attitudes. This is reported with varied levels of attitudes across the various geographical areas. The most important indicators of sustainable agriculture that the farmers had high attitudes towards include use of cover crops, green and animal manures, biological weed and pests control recycling of agricultural residue and intercropping. There was however low level of agreement among the maize farmers. Farm- and farmer-specific factors that significantly had positive influence on the levels of attitudes of famers towards sustainable agriculture include sex, marital status, years of formal education, household size, crop diversity, land size, yield and ownership of land. Those that had negative significant influence were age and number of sources of technical information. There were generally significant differences among the three geographical areas in terms of their level of agreement on the indicators for sustainable agricultural practices except intercropping, cover cropping, crop rotation, and integrated pest management. In all cases, there were no significant differences between the Middle and the Northern Volta. However, the Southern Volta was significantly different from both the North and the Middle Volta.

The most significant attitude indicators that influence farmers' level of sustainable maize production practices were the use of animal manure, biological pests and weed control, reduced tillage and nitrogen fertilizer rates.

The planetary or environmental sustainability indicators mostly practised by maize-farming households were reduced use of fungicides, pesticides and weedicides, and use of more stubble for mulching. The sustainable use of the agro-chemicals was mainly as the result of the inability of most farmers to afford more of these chemicals; hence they have resorted in the use of the ones they are able to acquire to enhance productivity. Other indicators that a number of farmers practise on sustainable basis were nitrate applications, weeding and soil resource management. Majority of the farmers from all the three geographical areas were involved in environmental sustainable agricultural practices. Social sustainability indicators were highly practised among the maize farmers in the Volta Region. However, only few of them had knowledge on conservation of fertilizer resources. Three economic sustainability indicators mostly practised by maize farmers in the area were efficient use of resources (seeds), planting in rows and crop diversification. Only few people were able to achieve economic sustainability more especially in the area of productivity and alternative income generation sources. There were significant differences in the sustainability indicators where social sustainability was significantly greater than environmental sustainability which was also significantly greater than economic sustainability.

Models for climate change responses, food security and sustainable agriculture

This study sought to establish the interconnectedness of climate change responses, food security and sustainable production practices using maize-farming households in the Volta Region of Ghana. In addressing this goal, the researcher proposed an integrated model comprised of various concepts and approaches. Results from the study provide support for most of the hypothesized paths. Most of the factors were found to influence food security with response to climate change effect being the most significant. Contrary to expectations, perceived climate change effect was found not to be a significant predictor of food security. The result of integrating several models is evident in the substantial predictive power achieved by the SEM. That is 53.1 percent of the target variable (food security) was explained by the model.

Contribution to Knowledge

First, the current study integrates different concepts and theories in the farming enterprises such as livelihood diversification, attitudes and practices of sustainable agricultural production, climate change responses and food security. The integration of these models allow the researcher to adequately represent a number of issues bordering on farmers' efforts to achieving food and livelihood security. This research therefore extends research in the area by bringing to bear experiences from the context of maize-farming households along the geographical zones in the Volta Region, which is said to be a microcosm of the country.

This study makes major contributions to existing literature by proposing an integrated models which incorporate various livelihood and economic models/theories and also empirically validating this proposed model with data from Maize farming households. The current study therefore, fills the knowledge gap in the literature on the complexity of the interrelationships among the key variables of the study among farmers in the Volta Region of Ghana. In practice, the proposed model could serve as a tool for change agents for improving livelihoods of farmers who are striving to make a living.

Recommendations

This study offers a number of important recommendations both for scholars who are currently researching on the adaptive capacity in response to climate change, food and livelihood security and sustainable production, and for government and development agencies in the food and agricultural sectors.

This study has several important recommendations for practitioners such as MoFA, NGOs, and development partners who are concerned with improving livelihoods of farmers. First, with FSI being the final target variable, adaptive capacity to climate change effects is most important explanatory variable. There is therefore the need to increase resilience of maize-farming households by encouraging them to adopt sustainable response strategies to climate change effects, which will improve their food security situations.

Secondly, livelihood diversification was the second most important variable in predicting food security. Alternative income generation activities and/or increase in the use of a number of improved varieties of maize for production is suggested to maize farmers in the study area. This will improve food security levels of the Maize farming households.

With constraints being the third most important predictor of food security, efforts to reduce the production and postharvest constraints in maize production would lead to improvement in the food security levels of the Maize farming households. This could be done by prioritising the constraints based on the reported rankings. For instance, to solve the problem of undercapitalisation, government policies that would increase access to both financial and non-financial resource to enable farmers acquire inputs that are adequate for optimum production should the implemented. In addition, government of Ghana could also offer subsidies on agricultural inputs to these maize farming-households in order to reduce the challenge of undercapitalisation.

Furthermore, since there is positive and significant relationship between food security and sustainable agricultural practices, there is the need to advocate for changing perceptions and attitudes of farmers towards sustainable agriculture. To do this, the two most important factors that must be attended to should be livelihood diversification and constraints to maize production. Farmers with myriads of constraining factors, which undermine their livelihood strategies to achieving food security, may not be bordered much about sustainability when the present conditions are not adequately met.

Enabling policy environments are crucial for the adoption of agricultural systems that deliver public goods (natural capital) alongside private goods (increased food and fibre) over time. In an attempt to encourage farmers to upscale sustainable intensification, there is the need for government and development partners to create systems that will benefit individual farmers while they contribute to addressing challenges such as improving natural capital, food security and social-ecological resilience. The sustainable intensification of agricultural systems should thus be seen as part of a wide range of initiatives and efforts to create greener economies that will lead to improving livelihoods and social equity, while significantly reducing environmental risks and ecological scarcities. There should be a system put in place where farmers benefit directly for improving or preserving the ecosystem. The government or NGOs and other development partners could do this by giving incentives for their contributions to defined services and practices that help improve socio-ecological sustainability. Options such as compensating farmers for no tillage and developing market chains where a sub-set of consumers will be willing to pay price premiums for products that are produced while preserving the ecosystem could also help promote sustainability among maize-farming households in the region.

Most of the crop failures in the study area were associated with either a lack or excess of rainfall. Precise and on-time climate forecasting by the Ghana Meteorological Agency can reduce the risks of crop failure and also help in the pre and post decision making processes for better agricultural yield. The value of climate forecasts diminishes if information is received after the number of decisions are made, therefore the forecasting should be on time and specific.

The evidence of the geographical location of the farming households having moderating effect on the improving food security through sustainable production practices suggests that, localising scientific climate prediction, and enhancing farmers' adaptive capacity in response to extreme climate events could reduce Maize farming households' vulnerability and improve area specific livelihoods.

Recommendations for further studies

One of the concerns of this study is the use of cross-sectional research design. Even though the researcher based his research model on well-established theories and an extensive review of literature, since farmer behaviour is dynamic, the use of a longitudinal design might have provided more confidence in the results.

Another concern is the use of data from only one region where ethnic and economic diversity is fairly homogeneous. The use of data from only one region makes it difficult to generalize results to the whole country. In the future, other researchers could consider using data from different parts of the country. It would also be interesting to examine adoption of sustainable agricultural practices across countries in Africa. This would make the result more representative and one could examine differences between Ghana and other countries. The result of a study that compares countries would be particularly useful to multinational development partners in developing specific strategies for specific countries within the African continent.

Moreover, the low to moderate predictive values in the SEM indicate that there are other important factors that determine food security and sustainable agricultural practices in the context of maize farming. This issue requires further consideration and research to identify and test additional drivers of food security and sustainable agricultural practices, and also to provide a more detailed understanding of how perceptions and attitudes are formed in the context of responding to climate change effects, production constraints and sustainable agricultural practices. It would also be interesting to explore the moderating role of experience and membership to farmer associations in modelling food security. Researchers could also include other variables that have been seen to impact on climate change response strategies, livelihood diversification and constraints to production to further improve the predictive power of the model.

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APPENDICES

Appendix A: Research Instrument used for Data Collection

UNIVERSITY OF CAPE COAST
COLLEGE OF AGRICULTURE AND NATURAL SCIENCES
SCHOOL OF AGRICULTURE
DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

CLIMATE CHANGE, FOOD SECURITY AND PRODUCTION SUSTAINABILITY OF MAIZE-FARMING HOUSEHOLDS IN VOLTA REGION, GHANA
RESEARCH INSTRUMENTS

The primary purpose of this study is to identify and highlight food security and sustainable production issues among maize-farming households in the Volta Region. Your ideas, experiences, comments and suggestions in Maize farming and household are very important for this study.
Please respond to the items sincerely and truthfully. In most of the sections, you will find statements followed by several possible options with corresponding codes (numbers). Indicate the answer(s) that best fits your response or code(s) that best suits you. Most of the questions may require only one response but there are few items requiring multiple responses. Few tables are also provided for completion. There is no right or wrong answer. The information you provide will be handled confidentially. You are also assured of anonymity of the reports that will come out of this study.

1. Questionnaire serial number: ______________________________
2. District: ______________________________
3. Community: ______________________________
4. GPS coordinates: Altitude (masl) ______________________________
   a. Latitude range ______________________________
   b. Longitude ______________________________
5. Date of interview: Day: ________ Month: ________ Year: ________
6. Name of farmer: ______________________________

A. BACKGROUND CHARACTERISTICS OF FARMERS

1. Sex .1 Female .2 Male
2. Age of farmer at last birthday: __________ years.
3. Marital status of farmer: .1 Single .2 Divorced/separated .3 Widowed .4 Co-habiting/consensual union .5 Married

4. Status of respondent in the household: .1 Head .2 Partner .3 Child Other: ________
5. Highest level of education .1 No formal education .2 Primary education .3 Adult literacy education .4 JHS/MSL .5 SHS/O' level .6 Diploma/Cert A (Agric/Teacher) .7 University Other (specify) ______________
6. Number of years of formal education: ___________ years
7. Main occupation: ____
8. (a)Household size (#): __________________________
9. Please indicate the number of your household members who fall within the age and sex categories

Age range (years)	Sex	
	Female	Male
< 15		
15 – 24		
25 – 54		
55 – 64		
> 65		

10. How many years have you been growing maize? ________________ years.
11. Starting from the most important to the least, please indicate the main sources of household income:
    .1 ____________________ .4 ____________________
    .2 ____________________ .5 ____________________
    .3 ____________________ .6 ____________________
12. What is/are your main purpose(s) of growing maize?
    ____
    ____
13. What **major crops** do you produce in addition to maize?
    ____________________ ____________________
    ____________________ ____________________
    ____________________ ____________________
    ____________________ ____________________
14. Please indicate the number of plots of total land and sizes you have for all your farming activities?

Sites	Size (acres)

15. What is the total land size that you have been using for all your farming activities? ________ acres

B. MAIZE PRODUCTION ACTIVITIES

1. What is the main method of land preparation for your maize production?
.1 Slash and burn .2 Slash no burn .3 Mechanized preparation .4 Bush burning .5 Spraying with weedicide Others (specify) _____

2. Please indicate the major maize varieties you grow on your farm.
.1 ____________ .2 _________________ .3 _____________ .4 _____________ .5 ____________ .6 _________________ .7 _____________ .8 _____________

3. Why do you prefer growing these varieties of maize you have chosen?
.1 Disease resistance .2 Pest tolerant .3 High yielding .4 High Market demand .5 drought tolerant .6 Taste .7 Stores longer .8 High nutritional value .9 Availability Others (specify)
____

4. Where did you get maize seeds from? .1 Home grown (Farmer Saved) .2 Ordinary market/shop .3 Another farmer (family and friends) .4 Recommended stockiest (Seed stores) .5 SADA .6 MiDA .7 Co- operative society .8 Government Other (specify) ______________________

5. Why this source(s) of maize seed? ____

6a. Do you receive information from other persons or agencies on maize farming?
.1Yes .0 No

6b. If yes, list the source(s) of information on maize farming. _____________________

7. During which months do you plant maize last year? First season ____ Second season ____

8. Please indicate your date of planting, area planted and yields obtained in the last year maize farming.

Season	Size (acres)	Date planted (dd/mm/yyyy)	Yield (kg)	Qty consumed (kg)	Qty sold (kg)	Unit price (GHS)	Total Amount
Major							
Minor							

9. What title(s) do you hold to the land you are using for maize farming?
.1 Own land .2 Family land .3 Cash Rental .4 Leasehold .5 Share cropping .6 Others (specify) ________________________________

10. Do you irrigate your maize farm? .1 Yes .0 No

11. How do you grow your maize? .1 Monocropping .2 Mixed cropping .3 Both .4 Seasonal .5 Continuous .6 Relay

12. What other crops did you intercrop with the maize? .1 ____________

.2 ____________ .3 ____________

.4 ____________ .5 ____________

13. Was maize planted in rows? .1 Yes .0 No

14. What spacing did you use in planting your maize (inter by intra rows)? ___ cm X ___ cm.

15. How many seeds per hill/hole? ____________

16. Was the seed dressed/treated before planting? .1 Yes .0 No .3 Don't know

17. How many times do you apply fertilizer on your maize farm during last season? __ times

18. Please indicate your fertilizer application activities on your maize farm during last year.

Application	Type(s) of fertilizer applied	When/Stages applied	Amount per acre	Method of application	What did you use to apply the fertilizer	Total cost of fertilizer
1st Application						
2nd Application						
3rd Application						

19. What is your source of the fertilizer you used last year? .1 Left over from previous year .2 From other farmers .3 MiDA .4 SADA .5 Input dealers .6 Farmers groups Others (specify) ____________

20. Do you apply manure on your maize farm? .1 Yes .0 No

21. Source of manure: .1 Own farm .2 Farmers in same community .3 Farmers in another community Others (specify) ____________

22. How do you finance your Maize farming activities?
 .1 Own savings .2 Relatives and Friends .3 Bank .4 Money lender
 .5 NGO .6 Cooperative/Credit Union .7 Others (specify) ____________

23. Apart from your own savings, how much credit did you receive from other sources for Maize farming activities? GHS ____________

24. At what interest rate did you repay the amount borrowed? _______%

C. CROP PROTECTION

1. How do you control weeds on your maize farm? .1 Use of weedicides .2 Use of cutlass/hoe .3 Hand picking Others (specify): ___________

2. How many times do you control weed on your maize farm per season? _______ times.
3. When was (were) the weeding done? 1st weeding_______ 2nd Weeding ________
4. How did you dispose of the maize residue after harvesting? 1. Left on the field to rot .2 Cut and/or burn .3 Used as animal feed .4 Others (specify) _____
5. Did you experience severe diseases in your maize farm last year? .1 Yes .0 No
6. Did you experience severe pest problem in your maize farm last year? .1 Yes .0 No
7. Did you experience severe nutrient deficiency problems in your maize farm last year? .1Yes .0 No
8. How many times did you apply the following agro-chemicals on your maize farm during last season?

Agro-chemical	How many times applied	Quantity/acre (Litres)	Total cost/acre (GHS)
Weedicides			
Insecticides			
Fungicides			

D. OTHER INPUTS AND OUTPUT INFORMATION

1. Equipment owned

Tools	Number	Unit cost (GHS)	How many years old?
i. Cutlass			
ii. sprayer			
iii. Hoe			
iv. Watering can			
v. Plough			
vi.			

2. Land owned

Item	Size (acres)	Cost per acre (GHS)	Total cost (GHS)
Land			

3. Planting Material used

Item	Quantity (kg)/acre	Unit cost (GHS)	Total cost (GHS)
Seeds			

4. Please indicate the number of persons, hours and days used in production activities

Type		Number of persons	Hours used per person per day	Days worked per crop season	Wage per person per day (GHS)
Hired					
Family	Male > 18yrs				
	Female > 18yrs				
	child (under18)				

5. Please indicate how much you paid (GHS) for the following activities per acre during

Activities	Ploughing	Harrowing	Sowing	Fertilizer application	agro-chemical applications	Harvesting	Shelling	Transportation from farm
GH¢								

the last Maize farming season:

6. Were any cobs harvested green to sell? .1 Yes .2 No
7. If yes, what was the yield of the green cobs (specify units)? ________________
8. How much revenue did you get selling the maize that you harvested green? GHS _____
9. Why did you harvest the fresh green cobs? ______________________________

E. PERCEPTION ON CLIMATE CHANGE AND PRODUCTION SUSTAINABILITY

1. Please indicate whether there have been changes in the following climatic conditions, and if there is any change what kind of change, and how do you think they influence the yields, weeds, and pest and diseases on your maize farms? Please use the following levels of measurement:

1 = Increase 2 = Decrease 3 = No change 4 = Fluctuating

Climatic Conditions	**Change in conditions**	**Effects of Changes in climate on**						
		Reduce maize yield	**Reduce soil fertility**	**Increase disease & pest**	**Increase weed control**	**Difficulty in Postharvest handling**	**Reduce water levels**	**Reduce vegetation cover**
Temperature								
Rainfall								

2. Please indicate by ticking any of the following adaption practices that you use to avert the negative effect of climate change impact in your farming activities

Response strategies	Response
Planting residue retention /mulching	
Crop diversification	
Planting across the slope	
Planting multiple periods in a season	
Use of multiple locations for maize production	
Prompt weeding	
Changing planting dates	
Diversification of enterprises	
Extension services	
Use of mixed cropping	
Use of fertilizer	
Intercropping	
Seed priming	
Seed dressed/treated before planting	
Use of cover crops	
Biodiversity conservation	
Regulated herbicides use	
Use of green manure	
Use of multiple varieties	
Use of crop rotation	

Response strategies	Response
Reduced tillage	
Change variety of maize produced	
Use of improve varieties	
Regulated pesticides use	
Conservation tillage	
Consulting experts on production	
Application of manure	
Selling fresh corns	
Planting pest tolerant varieties	
Planting drought tolerant varieties	
Planting of economic trees	
Planting disease resistance varieties	
Agroforestry	
Use of improved storage technologies	
Planting weed tolerant varieties	
Use of early maturing seeds	
Planting only certified seeds	
Use of irrigation	
Weather forecast services	
Any other (specify)	

3. Please indicate the extent to which you agree with the following statements as sustainable agriculture practice in Maize farming by circling the appropriate number on a 10-point scale (Strongly Disagree (1) to Strongly agree (10))

Sustainable Agricultural Practice	Level of agreement									
1. Intercropping	1	2	3	4	5	6	7	8	9	10
2. Cover cropping	1	2	3	4	5	6	7	8	9	10
3. Crop rotation	1	2	3	4	5	6	7	8	9	10
4. Row banding of herbicides	1	2	3	4	5	6	7	8	9	10
5. Integrated pest management	1	2	3	4	5	6	7	8	9	10
6. Use of green manure	1	2	3	4	5	6	7	8	9	10
7. Use of animal manure	1	2	3	4	5	6	7	8	9	10
8. Reduced rates of herbicides	1	2	3	4	5	6	7	8	9	10
9. Reduced nitrogen fertilizer rates	1	2	3	4	5	6	7	8	9	10
10. Reduced use of fertilizers	1	2	3	4	5	6	7	8	9	10
11. Reduced tillage	1	2	3	4	5	6	7	8	9	10
12. Recycling agricultural wastes	1	2	3	4	5	6	7	8	9	10
13. Biological control (use of microorganisms)	1	2	3	4	5	6	7	8	9	10
14.										

F. CONSTRAINTS ASSOCIATED WITH MAIZE PRODUCTION

1. Please identify and rank the constraints you faced in the production of maize during the last season

(a) Production constraints	Rank
1. Undercapitalization	
2. Low yield	
3. Insufficient extension services	
4. High cost of inputs	
5. Difficulty in accessing labour	
6.Diseases infection	
7. Pests infestation	
8. Difficulty in weed control	
9. Land tenure insecurity	
10. Difficulty in accessing credit	
11. Difficulty in accessing certified seeds	
13. Others (specify)	

(b) Postharvest Constraints	Rank
1.Post-harvest losses	
2.Uncertain demands	
3.Unremunerative prices	
4.Inadequate storage facilities	
5.Lack of market information	
6.High transportation cost	
7.Lack of crop insurance	
Others (specify)	

G. FOOD SECURITY AND SUFFICIENCY

1. Does the family experience food deficit? .1 Yes .2 No
2. Please indicate the number of months within which you ever had food deficits in the household for the year: 2011 ______, 2012 _______, 2013 _______, 2014 ______ and 2015 _______
3. In general which of these statements best describes the availability of foods eaten in your household in last year?
   - .1 We **always** have enough and the kinds of foods we wanted
   - .2 We have enough to eat but **not always** the kinds of foods wanted
   - .3 **Sometimes,** we don't have enough we wanted
   - .4 **Often** we don't have enough of the kind of food we wanted
4. In order to have enough food and the kinds of food you want for your household would you need to spend: .1 More than you do now .2 the same amount .3 less than you do now.
5. About how much more would you need to spend each month on food to meet the food needs of your household: GHS_______________.
6. Please indicate and rank the strategies you mostly adopt to avert food insecurity

Strategy	Ranking
Consumed less preferred foods	
Reduce food intake	
Change the diet	
Skipped meals	
Mixed farming	
Selling non-productive assets	
Searching for wild foods	
Engage in off-farm activities	
Engage in non-farm activities	
Household look for work elsewhere	
Borrowed money from friends and relatives	
Borrowed food from friends and relatives	

H. Household Food Security Status

1. Food Consumption score

How many days over the last 7 days, did members of your household eat the following food items, prepared and /or consumed at home and what was there source. (Use the codes below; write 0 if not consumed in last 7 days). Note for enumerator: determine whether consumption of fish, milk was only in small quantities			
	Foods	Number of times eaten in past 7 days. If 0 days, do not specify the main source.	How was this food acquired? Write the main source of food for the past 7 days.
1.	Cereals, grains, roots and tubers, rice, bread, maize, potato, yam, cassava, millet.		
2.	Legumes/ nuts: beans, cowpea, peanuts, palm nuts.		
3.	Milk and other dairy products: fresh milk, sour, yogurt, other dairy products (exclude margarine, butter or small amount of milk for tea or condiments)		
4.	Meats, fish and eggs: goats, beef, chicken, pork, fish, including canned tuna, egg, (meat and fish consumed in large quantities and not as condiment).		
If 0 – skip to question 5			
4.1	Flesh meat: pork, beef, lamb, goat, rabbit, duck, chicken, other birds.		
4.2	Organ meat: liver, kidney, heart and/or other organ meats.		
4.3	Fish or shell fish: fish, including canned tuna, and/or other sea foods (fish in large quantities not as a condiment).		
4.4	Eggs		
5.	Vegetables and leaves: onion, tomatoes, carrots, pepper, green grains, lettuces, garden eggs.		
If 0 – skip to question 6			
5.1	Orange vegetables (vegetables rich in vitamin A): carrots, red pepper.		
5.2	Green leafy vegetables: cassava leaf, cocoyam leaves, lettuces.		

6.	Fruits: banana, apple, mango, pineapple, orange,		
If 0 – skip to question 7			
6.1	Orange fruits (fruits rich in vitamin A): mango, papaya.		
7.	Oil/fat/butter: vegetable oil, palm oil, Shea butter, margarine, other fat or oil.		
8.	Sugar or sweet: honey, candy, pastries, cake and other sweet (sugary drinks)		
9.	Condiment or spices: tea, milo, coffee, salts, garlic, spices, tomato, meat or fish as a condiment, condiment including small amount of milk or tea coffee.		

Food acquisition codes	5=Market (purchased with cash)	9=Gifts (food) from family relatives or friends.
1=Own production (crops or animal)	6=Market (purchased on credits)	10=Food aids from civil societies, NGOs, Government.
2=Fishing or hunting	7=Beg for food	
3=Gathering	8=Exchange labour or items for food.	
4=Loan		

2. Food quantity module (Energy shortfall)

Within the past 7 days did household members eat/drink any … within the household?	Yes=1 No=2 >Next	How much in total did your household consume in the past 7 days.		How much came from purchases during the past 7 days.		How much did you spent?	How much came from your own production?		How much came from gifts and other source?	
		Unit	Qty	Unit	Qty	GHS	Unit	Qty	Unit	Qty
		Cereals and cereals products								
Maize (green)										
Maize (dry cob)										
Rice (paddy)										
Rice (husked)										
Millet										
Sorghum										

3. Food Consumption Basket Value module (Food expenditure)

		3.01-Did your household purchase any of the following items during the last 30 days for domestic consumption? If No, enter 0 and proceed to 3.02 If Yes ask the respondent to estimate the cash and credit expenditure on the item for 30 days. (register the expenses according to local currency)		3.02-during the last 30 days did your household consumed the following food without purchasing them? 0=No – skip to next food group row 1=Yes.	3.03-Estimated value of non-purchased item consumed during the last 30 days. This question refers to the consumption reported in 3.02.	3.04- What is the main source of non-purchased food group? 1=Own production 2=Gathering/ hunting. 3=Donation/food aid/gift 4=Received in exchange for labour /items. (This question refers to the consumption reported in 3.02).
		(Cash, GHS)	(credit, GHS)		(GHS)	
1.	Cereals (maize, rice, sorghum, wheat, bread)					
2.	Tubers (sweet potato, cassava, yam, cocoyam)					
3.	Pulses (beans, peas, groundnuts)					
4.	Fruits and vegetables					
5.	Fish/meat/eggs/poultry					
6.	Oil, fat, butter					
7.	Milk					
8.	Sugar/ salts					
9.	Tea/coffee/milo					
10.	Other meals/ snacks consumed outside the home.					

4. Household Non-food Expenditures

	3.04- -Did your household purchase any of the following items during the last 30 days for domestic consumption? If none, write 0 and go to next item	3.05-Estimated expenditure during the last 30 days (Register the expenses according to the currency in which it was done). (GHS)	3.06-in the past 6 months how much money have you spent on each of the following items or service? Use the following table, write 0 if no expenditure.		3.07-Estimated expenditure during the last 6 months. (GHS)
1.	Alcohol/palm wine		8.	Medical expenses, health care.	
2.	Soap		9.	Clothing, shoes	
3.	Transport		10.	Education, school fees, uniform.	
4.	Fuel (Wood)		11.	Debt repayment	
5.	Water		12.	Agricultural inputs	
6.	Rent		13.	Savings	
7.	Electricity		14.	House repairs	

5.a Livelihood-based coping strategies

	3.01	3.02
During the past 30 days did anyone in your household have to engage in any following behaviors due to lack food or lack of money to buy food?		If no please clarify:
	1=Yes	1=No, because it wasn't necessary
	2=No- clarify response in next column (3.02)	2=No, because I already sold those assets or did this activity with the last 12 months and I cannot continue again.
		3=Not applicable.
1.1-sold household assets/goods (radio, furniture, refrigerator, television, jewelry)		
1.2-Reduced non- food expenses on health (including drugs) and education.		
1.3-Sold productive assets or means of transport (sewing machine, wheel barrow, bicycle, car)		
1.4-Spent saving		
1.5-Borrowed money/food from a former lender/bank		
1.6-Sold house or land		

1.7-Withdraw children from school		
1.8-Sold last female animals		
1.9-Begging for food		
1.10-Sold more animals (non-productive) than usual		

5.b Food consumption-based coping strategies.

2.02 During the last 7 days, were there days (and, if so, how many)when your household had to employ one of the following strategies (to cope with a lack of lack of food or money to buy it)	Frequency (number of days from 0 to 7)
1. Rely on less preferred food	
2. Rely on less expensive food	
3. Borrow food from friends or relatives	
4. Borrow money to buy food	
5. Purchase food on credit	
6. Rely on help from relatives or friend outside household without having to pay back.	
7. Limit your own intake to ensure child gets enough	
8. Limit portions at mealtimes	
9. Reduce number of meals eaten in a day	
10. Skip whole day without eating	

Suggestions for improving Maize farming activities in your area:

____

____

____

____

Thank you very much for your time and efforts.

Appendix B1: Example of completed CARI reporting console

Domain		Indicator	Food Secure (1)	Marginally Food Secure (2)	Moderately Insecure (3)	Severely Insecure (4)
Current Status	Food Consumption	Food consumption score	51%		36%	13%
		Food energy shortfall	*n/a*	*n/a*	*n/a*	*n/a*
Coping Capacity	Economic Vulnerability	Food expenditure share	8%	9%	11%	72%
		Poverty status	*n/a*	*n/a*	*n/a*	*n/a*
	Asset Depletion	Livelihood coping strategy categories	66%	19%	3%	11%
Food Insecurity Index			**6.9%**	**43.7%**	**42.7%**	**6.8%**

Source: WFP (2015).

Appendix B2: Example of completed CARI reporting console

Domain		Indicator	Food Secure (1)	Marginally Food Secure (2)	Moderately Insecure (3)	Severely Insecure (4)
Current Status	Food Consumption	Food consumption score	51%		36%	13%
		Food energy shortfall	*n/a*	*n/a*	*n/a*	*n/a*
Coping Capacity	Economic Vulnerability	Food expenditure share	8%	9%	11%	72%
		Poverty status	*n/a*	*n/a*	*n/a*	*n/a*
	Asset Depletion	Livelihood coping strategy categories	66%	19%	3%	11%
Food Insecurity Index			**6.9%**	**43.7%**	**42.7%**	**6.8%**

Source: WFP (2015).

Appendix C: The Garrett Ranking Conversion Table

GARRETT RANKING CONVERSION TABLE

The conversion of orders of merits into units of amount of "socres"

Percent	Score	Percent	Score	Percent	Score
0.09	99	22.32	65	83.31	31
0.20	98	23.88	64	84.56	30
0.32	97	25.48	63	85.75	29
0.45	96	27.15	62	86.89	28
0.61	95	28.86	61	87.96	27
0.78	94	30.61	60	88.97	26
0.97	93	32.42	59	89.94	25
1.18	92	34.25	58	90.83	24
1.42	91	36.15	57	91.67	23
1.68	90	38.06	56	92.45	22
1.96	89	40.01	55	93.19	21
2.28	88	41.97	54	93.86	20
2.69	87	43.97	53	94.49	19
3.01	86	45.97	52	95.08	18
3.43	85	47.98	51	95.62	17
3.89	84	50.00	50	96.11	16
4.38	83	52.02	49	96.57	15
4.92	82	54.03	48	96.99	14
5.51	81	56.03	47	97.37	13
6.14	80	58.03	46	97.72	12
6.81	79	59.99	45	98.04	11
7.55	78	61.94	44	98.32	10
8.33	77	63.85	43	98.58	9
9.17	76	65.75	42	98.82	8
10.06	75	67.48	41	99.03	7
11.03	74	69.39	40	99.22	6
12.04	73	71.14	39	99.39	5
13.11	72	72.85	38	99.55	4
14.25	71	74.52	37	99.68	3
15.44	70	76.12	36	99.80	2
16.69	69	77.68	35	99.91	1
18.01	68	79.17	34	100.00	0
19.39	67	80.61	33		
20.93	66	81.99	32		

Appendix D: Test of homogeneity of variances among farmers on sustainable production practice variables

Practices	Levene Statistic	df1	df2	Sig.
Intercropping	7.613	2	724	.001
Cover cropping	59.275	2	724	.000
Crop rotation	.363	2	724	.696
Row banding of herbicides	4.928	2	718	.007
Integrated pest management	10.019	2	719	.000
Use of green manure	113.820	2	721	.000
Use of animal manure	47.744	2	719	.000
Reduced rates of herbicides	1.920	2	711	.147
Reduced nitrogen fertilizer rates	.670	2	704	.512
Reduced use of fertilizers	4.892	2	714	.008
Reduced tillage	32.788	2	717	.000
Recycling agricultural wastes	20.384	2	721	.000
Biological control of weed and pests	56.976	2	711	.000
Composite practices	3.104	2	724	.045

Source: Field survey, Akaba (2018)

Appendix G: Response strategies adopted by maize farmers to avert negative climate effects

Response strategies	Geographical locations			Aggregates
	Northern	Middle	Southern	
Planting residue retention/mulching	75.5	83.6	90.2	83.1
Crop diversification	82.9	73.4	66.4	74.2
Planting across the slope	79.6	77.0	62.7	73.1
Planting multiple periods in a season	80.8	51.6	81.6	71.4
Use of multiple locations for maize production	80.0	59.4	57.8	65.8
Prompt weeding	67.8	40.2	76.6	61.5
Changing planting dates	53.9	43.9	81.1	59.6
Diversification of enterprises	43.3	58.6	73.8	58.5
Extension services	79.6	46.7	42.2	56.2
Use of mixed cropping	28.6	48.4	80.7	52.5
Use of fertilizer	60.4	42.2	39.8	47.5
Intercropping	25.7	35.2	80.7	47.2
Seed priming	26.1	55.3	58.6	46.7
Seed dressed/treated before planting	50.2	34.4	47.5	44.1
Use of cover crops	46.1	40.2	38.9	41.7
Biodiversity conservation	49.4	43.9	27.0	40.1
Regulated herbicides use	39.2	38.9	33.6	37.2
Use of green manure	40.4	39.3	27.5	35.7
Use of multiple varieties	31.4	25.8	36.1	31.1
Use of crop rotation	27.8	18.4	46.3	30.8
Reduced tillage	35.1	31.1	20.9	29.1
Change variety of maize produced	27.3	15.2	34.0	25.5
Use of improve varieties	27.3	15.2	34.0	25.5
Regulated pesticides use	208	18.4	24.2	21.1
Conservation tillage	21.2	29.1	6.6	19.0
Consulting experts on production	21.2	14.3	12.3	16.0
Application of manure	11.8	7.8	27.9	15.8
Selling fresh corns	23.7	15.2	5.3	14.7
Planting pest tolerant varieties	10.2	21.3	8.6	13.4
Planting drought tolerant varieties	12.7	4.5	22.5	13.2
Planting of economic trees	3.7	17.6	5.7	9.0
Planting disease resistance varieties	6.9	12.7	6.1	8.6
Agroforestry	6.5	12.3	5.3	8.0
Use of improved storage technologies	11.0	5.3	7.0	7.8
Planting weed tolerant varieties	3.3	7.8	11.1	7.4
Use of early maturing seeds	11.8	3.7	5.3	7.0
Planting only certified seeds	9.4	4.1	7.0	6.8
Use of irrigation	5.7	4.9	1.6	4.1
Weather forecast services	1.6	2.0	7.8	3.8