COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

CLIMATE-SMART AGRICULTURE AND FOOD SECURITY NEXUS: PRACTICES, ADOPTION STRATEGIES AND TECHNOLOGIES IN HIDHABU ABOTE *WOREDA*, OROMIA REGION, CENTRAL ETHIOPIA

BY

NAZRAWIT AYELE

JUNE 2019

ADDIS ABABA

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

CLIMATE-SMART AGRICULTURE AND FOOD SECURITY NEXUS: PRACTICES, ADOPTION STRATEGIES AND TECHNOLOGIES IN HIDHABU ABOTE *WOREDA*, OROMIA REGION, CENTRAL ETHIOPIA

BY

NAZRAWIT AYELE

THESIS ADVISER
MESSAY MULUGETA (PHD)

MSC THESIS SUBMITTED TO
CENTER FOR FOOD SECURITY STUDIES, COLLEGE OF DEVELOPMENT STUDIES ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN FOOD SECURITY AND DEVELOPMENT

JUNE 2019
ADDIS ABABA

ADDIS ABABA UNIVERSITY

DECLARATION

This thesis is my original work and has not been presented for a degree of master in any other University and that all the sources and materials used for the thesis have been properly acknowledged.

Declared By: Nazrawit Ayele

Signature: ________________

Date: ____________________

Place: Addis Ababa University, College of Development Studies, Center for Food Security Studies

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge as an advisor.

Dr. Messay Mulugeta ____________________ __________________
(Advisor) Signature Date

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared by Nazrawit Ayele Atlabachew entitled '*Climate-Smart Agriculture and Food Security Nexus: Practices, Adoption Strategies and Technologies in Hidhabu Abote Woreda, Oromia Region, Central Ethiopia'* submitted in partial fulfillment of the requirements for the Degree of Master of Science in Food Security and Development complies with the regulations of Addis Ababa University and meets the accepted standards with respect to originality and quality.

Signed by the examining committee:

External Examiner: ______________________Signature ___________ Date _______________

Internal Examiner: ______________________Signature ____________ Date _______________

Advisor: _______________________________Signature ____________ Date_______________

Name of Chairman ____________________Signature ____________ Date_______________

____

Chairperson of the Center or Graduate Program Coordinator

Acknowledgements

My greatest expression of thanks goes to the Almighty GOD (JESUS) for giving me the strength and the energy throughout the research process and HIS continues blessings upon my life.

Secondly, my appreciation and gratitude goes to my research advisor, Dr. Messay Mulugeta, whose encouragement, guidance and support from the initial to the end has made it possible for me to see the completion of my thesis. Other than his critical advisement, I am really grateful to Dr Messay for his brotherly and ever-welcoming approach throughout my study period. The moral and emotional support of Dr Messay is unforgettable forever. God bless you Sir with all your family!!.

I am thankful to the Capacity Building for Scaling up of Evidence-based Best Practices in Agricultural Production in Ethiopia (CASCAPE) project for funding this research.

I must in all sincerity express my deep gratitude to all experts in woreda-level sectors offices, especially Mr Ifa Demissie, for the time and information given to me.

I wish to express my profound gratitude to my friends Meklit Yoseph, Abreham Solomon, Elias Tilahun, Mena Eyesus, Hiwet Hailu, Zeritu Negusa and Tibletse fitsum who in diverse ways helped and motivated me during the writing of this thesis. I am also indebted to my family Mr Ayele and Mrs Mintamer, Fiker Ayele, Shalom Ayele, Dagmawi Tesfaye, Zerubabel Ayele, Natnael Ayele for their prayers and enormous support during my fieldwork. My special and heartfelt gratitude goes to my brother, Mr. Natnael Ayele, for the spare time from his busy schedule to accompany me for the fieldwork.

Nazrawit Ayele
JUNE 2019

Table of contents

Contents Page

Abbreviations

BBM	Broad Bed Maker
CASCAPE	Capacity Building for Scaling up of Evidence-based Best Practices in Agricultural Production in Ethiopia
CFCs	Chlorofluorocarbons
CSA	Central Statistical Agency
CSA	Climate Smart Agriculture
ENSO	El Niño-Southern Oscillation
FAO	Food Agriculture organization
GHGs	Greenhouse Gases
GDP	Growth Domestic Product
HAWAO	Hidhabu Abote *Woreda* Administration Office
HFIAS	Household Food Insecurity Access Scale
HHFBA	Household Food Balance Analysis
ILM	Integrated Landscape Management
IR	Industrial Revolution
KII	Key informant Interview
MoA	Ministry of Agriculture
NDV	Newcastle Disease Virus
NMA	National Meteorological Agency
ONRS	Oromia National Regional State
PCI	Precipitation Concentration Index
SACS	Saving and Credit Services
SSA	Sub-Saharan African
UNDP	United Nations Development Programme
WFP	World Food Program

List of Table

List of Figures

List of Appendices

Abstract

This study was undertaken in 3 randomly selected rural kebeles in Hidabo Abote Woreda of North Shewa Zone, Oromia Regional State. The study aimed at assessing the contribution of climate smart agricultural practices for crop productivity, food security, livelihoods enhancement and adaptation to climate change. Retrospective-cross-sectional study design was employed and questionnaire-based primary data was collected from 200 randomly selected sample households. In addition, key informant interview and direct observation were employed to generate qualitative data. In fact, secondary data was obtained from various related organizations such as NMA, CSA and the Woreda Agricultural Office. Latest version of SPSS software was used to explore key descriptive and inferential statistics. Household Food Balance Model (HFBM) and Household Food Insecurity Access Scale (HFIAS) were used to investigate the availability, consumption and access components of household food security status. The sustainability component was addressed by analyzing the trends and current circumstances of rainfall and temperature in the area. Precipitation Concentration Index (PCI) and Coefficient of Variation (CV) were used to look into the level of concentration of rainfall to certain months of a year and variations in rainfall among series of years (1983-2016). It is found that the rainfall is highly concentrated, the variation among years is noticeable and temperature is slightly increasing in the area. The farmers have already started mulching, inter-cropping, agro-forestry, crop rotation, improved seed application and water harvesting to cope with the adverse impacts of climate change. It is also found that most farmers perceive the existence of climate change in the area as a result of which they are trying to design their own adaptation mechanisms. Among other variables, age of the household head, income status, asset position, farmland size, access to extension services, experience in agriculture, distance, fertilizer application, family size, and crop- diversification are found to be important determinant factors for CSA practices in the area. In order to harness the best out of CSA practices as a means to adapt to the changing climatic conditions in the area, compressive planning, well thought-out and genuine strategies, adequate understanding of the implementation practices, efficient and effective utilization of natural resources and competent expertise/leadership are recommended to be vital.

Keywords: *Climate-Smart Agriculture, Adoption, Climate Change, Food Security,*

1. CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Food and Agricultural Organization of the United Nations (FAO, 2013) estimates that agricultural production has to increase by 60% by 2050 to satisfy the expected demands for food and feed across the world. Most of the additional 2 billion people will live in developing countries (Williams, *et al.*, 2015). At the same time, 70% of the people (against the current 50%) will be living in urban areas by 2050 (UN, 2014). This fast rate of urbanization and the rising incomes in developing countries are becoming vital driving forces for the increment of consumption of agricultural products. FAO (2015) argues that agriculture must transform itself if it is to feed a rapidly growing global population and fast rate of urbanization. Attempts to increase productivity, in turn, adversely affect the environment unless eco-friendly production systems are in place to protect the environment for sustainable agricultural production. It is with this broad understanding that the concept of climate-smart agriculture (CSA) has come in to the academic discourse.

It is required to provide the basis for economic growth and poverty reduction as well. Climate change is adversely impacting agricultural activities and will make this task more difficult under *a business-as-usual scenario*, due to adverse impacts on agriculture, requiring spiraling adaptation and related costs (Nelson, 2009). This calls for climate-smart agriculture that helps to guide actions needed to transform and re-orient agricultural systems to effectively and efficiently support development and ensure food security in the changing climate.

FAO (2013) indicates that to achieve food security, adaptation to climate change and lower emission intensities per agricultural output are vital. This agricultural transformation needs to be accomplished without depletion of the natural resources such as soil, water and vegetation. In fact, climate change is already having an impact on agriculture and food security as a result of increased prevalence of extreme climatic events and increased unpredictability of weather patterns (Manyeruke, *et al*, 2013). This can lead to reductions in production and lower incomes in vulnerable areas (particularly rural areas) and affect global food prices FAO (2013). Developing countries and smallholder farmers and pastoralists in particular are being especially hardly hit by these changes. Many of these small-scale producers are already coping with a degraded natural resource base (Chnig, 2010).

The smallholders often lack knowledge about potential options for adapting their production systems and have limited assets and risk-taking capacity to access and use technologies and financial services. For the abovementioned practical reasons, agriculture is required to improve and ensure food security, and to do so it needs to adapt to changing climatic conditions and natural resource pressures. It is also required to contribute for mitigating climate changes and these challenges, being interconnected, have to be addressed simultaneously. This is because agriculture is a significant driver of environmental degradation. Deforestation, depletion of wetlands and grassland being converted to cropland induces higher carbon emissions, and reduces capacity for carbon sequestration. Hence, as indicated in SIDA (2017), improvement of crop yields (productivity increase) rather than expansion of cropland should be prominent in any mitigation strategy. In 2016, the number of undernourished people in the world increased to an estimated 815 million, up from 777 million in 2015. Similarly, while the prevalence of undernourishment is projected to have increased to an estimated11 percent in 2016, this is still well below the level of a decade ago. Nonetheless, the recent increase is cause for great concern and poses a significant challenge for international commitments to end hunger by 2030 (FAO, 2016).

For the poor smallholder producers like the rural people in Hidhabu Abote *Woreda* (study area), food is not only a basic need, it is also the single and often fragile resource for maintaining livelihoods of the farmers. Hence, climate-smart agriculture and/or eco-friendly agricultural practices are considered to be vital to ensure food security through ensuring availability of calories, sufficient production, accessibility to everyone and proper utilization in the right diversity and stability. Hence, this study is planning to investigate the nexus between climate-smart agriculture and food security in Hidhabu Abote *Woreda* through investigating evidence-based existing practices, and adoption strategies and technologies in the area.

2. Statement of the Problem

The agricultural sector in Ethiopia uses low capital intensive agricultural technologies resulting in low productivity and income that constrain farmers' capacity and options to adaptation under climate change (Dinar et al., 2008). The sector is largely rain-fed and the country's economy heavily relies upon it. Agriculture accounted for 43% of GDP in 2013. It generates over 70% export values and employs 85% of the total labor force (UNDP, 2014). Ethiopia, like many African countries, is highly vulnerable to climate change. This vulnerability has been demonstrated by the devastating effects of the various prolonged droughts in the 20th century. WB,2009; Aklilu &Alebachew 2009 as cited in Bewket *et* al. (2015) asserted that there is all increased incidence of meteorological drought episodes, famines and climate-sensitive human and crop diseases in the northern highland and southern lowland regions of Ethiopia.

Climate change is a serious threat for agriculture, food security and fight against poverty in Sub-Saharan Africa in general and in Ethiopia in particular (UNFCCC, 2007). Crop failure due to unexpected and recurrent climate shock incidences such as drought (shortage of rainfall) and flooding (excessive rain) increase a risk of longer period of hunger and more severe livelihood hardship of many rural poor who rely on small-scale farming for food and income across the world.

This is a reality in Hidhabu Abote *Woreda* where the rural people are pushed into the four statuses of food insecurity due to agro-climatic adversities along with socioeconomic and policy predicaments. Despite the expansion of Ethiopia's economy over the last decades (NPC, 2016), the number of food insecure and relief-assisted population in the country has been extremely high in recent years (Abduselam, 2017). In 2017, for example, the country faced one of the severest food shortages in which over 10 million people suffered from lack of food in Ethiopia (NDRMC, 2017). In the same way, empirical evidences show that the study area district, experiences a climatic variability factor mainly in the form of irregular rainfall in amount (precipitation) and distribution that induced low productivity in the area. Steady population growth, deforestation, poor land management and soil loss are other major limiting factors to household food security.

This calls for proper formulation, implementation and diffusion of agricultural adaptation practices to climate change factors to build resilience, enhance food security and to reduce vulnerability. This research, therefore, aims to assess how farmers cope with climate-related agricultural production shocks using local and nationally identified agricultural adaptation practices to ensure household food security.

3. Objectives of the study

3.1. General objective

The general objective of this thesis is to assess how farmers cope with climate-related agriculture production shocks using local and nationally identified agricultural adaptation practices and technologies to ensure household food security in responses to climate extreme impacts on agricultural production in Hidhabu Abote district.

3.2. Specific objectives

More specifically, the study aspires to:

- ✓ explore the trends and patterns of rainfall and temperature changes in the area;
- ✓ look into the farmers' perceptions towards climate variability/change in the *woreda*;
- ✓ investigate climate related hazards/extremes affecting the agricultural sector in the study *woreda*;
- ✓ identify the existing climate-smart agricultural (CSA) practices intended to mitigate climate related predicaments in agricultural sector in Hidhabu Abote *woreda;*
- ✓ explore determinants of CSA practices in Hidhabu Abote *woreda*;
- ✓ Assess nexus between household food security and CSA practices.

4. Research Questions

This research intended to answer the following basic questions which are derivatives of the abovementioned research objectives:

- ✓ How farmers are practicing climate-smart agricultural activities in Hidhabu Abote *woreda*?
- ✓ What do the trends and patterns of rainfall and temperature changes look like in Hidhabu Abote *Woreda*?

- ✓ How the farmers are prepared to take up climate-smart agricultural innovations?
- ✓ What are the experienced impacts of climate change on crop production by the smallholders?
- ✓ What are the socioeconomic consequences of climate change impact?
- ✓ What are the overall policy and institutional strategies in place related to climate-smart agriculture in the area?
- ✓ How the institutions are functioning to enhance climate-smart agricultural practices in the area?

5. Scope of the study

The study has limited spatial scope i.e. Hidhabu Abote *Woreda*. The study area was selected purposively. The study considers only smallholder farming households from each agro-climatic zones.

6. Limitation of the study

It has also delimitation in that it focused on to investigating the issue under study only from the crop and livestock production system of the agriculture sector. Thus, this research being one of the few preliminary works, it has limitation in generalizing findings to broader scope. This study may have limitation with regard to data acquisition (in amount and time horizon) as a result of limited available financial and time resources.

7. Significance of the study

Various researches have been conducted with regard to climate change impact and adaptation to agriculture and food security at national, regional and global levels. However, there are only small number of researches on climate-smart agriculture with empirical evidences in Ethiopia. The output of this research, therefore, are deemed too fill the knowledge gap in local and institutional responses to climate change in view of the climate-smart agricultural practices. It will help to show synergy between climate-smart and food security based on empirical evidences from the study area. The output of the study will also be benefiting other researchers in that the study will adapt and enhance methodologies suitable to investigate the nexus between the two issues: food security and climate-smart agriculture. Policy makers, local administrators would be benefiting from the output of the study as it will provide them with empirical and scientific evidences for the readers. Generally, this study, aims to contribute to the existing academic knowledge by exploring the climate change adaptation agricultural practices so as to contribute to household food security at local level.

8. The research ethics

The researcher recruited the respondents of the study in H/Abote *Woreda* of the study by maintaining assents of the participants by explaining the objectives and the study and how the findings of the study would be used. According to Levine (1988), assent is a term used to express willingness to participate in research by persons who are by definition too young to give informed consent but who are old enough to understand the proposed research in general, its expected risks and possible benefits, and the activities expected of them as subjects. Levine (1998) presents assent can be taken for people who might have trouble understanding the longer and often more detailed informed consent form. The assent form allows them to say ‘Yes’ or ‘No’ to the research, even if they don’t understand everything about it. In this study the researcher explained the overall objectives of the study and how the data might be used for the participants. In some instances, they were not willing to complete questionnaire, to give their voice to record and to take photograph and to participate at all. Others reported also that some interviews brought undesirable actions that removed them from their work resulted at them. In every stage of the data collection, analysis and reporting the anonymity of the participants of the study was kept.

9. Organization of the study

This thesis is organized in five major chapters. The first chapter included background, statement of the problem, objectives of the study, significant of the study and scope and limitations of the study. The second part deals with literature review that includes conceptual and theoretical frameworks of CSA practice and empirical studies made in the country and elsewhere in the world. The third chapter presents description of the study areas and methodologies used for the study. The findings of the study are presented in the result and discussions part in chapter four. Finally, chapter five presents conclusion and recommendations that are drawn from the study.

CHAPTER II: RELATED LITERATURE REVIEW

This chapter presents an overview of the theories and concepts of the themes of this thesis. Impacts of climate change on food security and agriculture, climate-smart agriculture *vs* conventional agriculture, approaches to climate-smart agriculture, practices, adoption strategies and technologies in climate-smart agriculture, and climate smart agriculture and food security nexus are the most important concepts that are comprehensively addressed. The chapter then concludes by providing the empirical conceptual framework depicting the nexus between climate-smart agriculture and food security in Ethiopian context.

2.1. Climate-smart agriculture (CSA): The concept

Now (*i.e.* 2018) it is about eight years since the meaning and definition of the term '*climate-smart agriculture*' has evolved, in particular in relation to the concept of sustainable agriculture. An important question is how does CSA differs from sustainable agriculture? CSA was defined by FAO (2010) as agriculture that sustainably increases productivity, enhances resilience of livelihoods and ecosystems, reduces and/or removes greenhouse gases (GHGs) and enhances achievement of national food security and development goals. CSA helps ensure that climate change adaptation and mitigation are directly incorporated into agricultural development planning and investment strategies. CSA is considered as a combined policy, technology and financing approach to enable countries to achieve sustainable agricultural development under climate change. The CSA approach involves the direct incorporation of climate change adaptation and mitigation into agricultural development planning and investment strategies. The magnitude of the need for adaptation and the potential for mitigation in agricultural development has major implications for successful agricultural development planning to support food security and poverty reduction. This, together with the potential of obtaining significant levels of climate-related financing in addition to traditional sources of agricultural investment finance, justify a strong and specific focus on integrating climate change adaptation and mitigation into agriculture development planning. CSA encompasses sustainable agriculture, expanding it to include the need for adaptation and the potential for mitigation with associated technical, policy and financing implications.

2.2. Impacts of climate change on agriculture and food security

Ever since the Industrial Revolution (IR), especially since 1950s, anthropogenic sources are slowly changing the composition of the natural atmosphere resulting in climate changes that can be depicted in the form of increasing temperature conditions, spatiotemporal rainfall variability, and the frequency and intensity of extreme weather events (Anderson, 2005). The chemical composition of the natural atmosphere and stratosphere is an important factor determining the temperature of the earth's surface and its climate. The amount of heat trapped depends on the concentration of the heat-trapping gases (greenhouse gases). These gases are mostly generated from fossil fuel burning, deforestation and wild fires, manufacture industries, landfill waste sites, burning and decay of biomass, enteric fermentation from ruminants, use of chemical fertilizers, and use of chlorofluorocarbons (CFCs) (Landry, *et al*, 2016), This results in the rise of the greenhouse gases concentration in the atmosphere which in turn has given rise to global temperature what is commonly known as climate change (IPCC, 2014).

Climate change is adversely impacting agriculture in several ways. One such example is the fact that an increase in the concentration of greenhouse gases in the atmosphere and the consequent global warming results in the rise of sea level because of thermal expansion and the melting of mountain glaciers (UNFCCC,2007), diminishing farmlands around sea borders. The rise in sea level is associated with a potential danger of inundating coastal farmlands and loss of large areas of precious agricultural areas to the sea (Savage, 2006). In fact, in formerly colder area unsuitable for crop production can be put under cultivation and there can be a rise of yield in some areas of the world. On the other hand, some places are becoming drier like thereby giving rise to the decline of crop yield owing to lack of adequate moisture. A warmer part of the world, such as Ethiopian lowlands (Messay, *et al*, 2017), is likely to have water crises in some parts while in other regions it will be wetter than today resulting flooding of agricultural lands. As indicated by Retallack (2001), there will be changes in natural ecosystems with grasslands and deserts expanding and forest areas shrinking. Soils become drier as evaporation rate rises. Surface water resources, such as lakes and reservoirs may shrink and even dry up heavily adversely affecting the aquaculture and other agricultural activities around the water bodies. (Biol, *et al* 2010), indicates that climate change may also exacerbate the spread of tropical diseases which, in turn, adversely affects health of the farmers unfavorably having an effect on their power and time of agricultural activities.

The past several decades have witnessed warmer temperatures across all regions; with a faster warming rate occurring in the latter half of the 20th century compared with the first half and increased climate variability. Heavy rainfall events have increased, longer and more intense droughts have occurred, and the El Niño-Southern Oscillation (ENSO) phenomenon has become the dominant mode of climate variability in many regions particularly in Ethiopia, exerting a significant influence on the prevalence and severity of drought and flooding in the tropics (Trenberth *et al*. 2007).

Climate change, through its spatiotemporal rainfall variability and temperature increase, is exacerbating the challenge in the agricultural sector across the world. Climate change induced increases in temperatures, rainfall variation and the frequency and intensity of extreme weather events are adding to pressure on the global agriculture system which is already struggling to respond to rising demands for food and renewable energy fueled by population increase. The frequency and intensity of extreme rainfalls are flooding the farmlands as well as the scarcity of rainfall is creating intense moisture scarcity in the sector leading to diminished agricultural outputs. The changing climate is also contributing to resource problems beyond food security, such as water scarcity, pollution and soil degradation. As resource scarcity and environmental quality problems emerge, so does the urgency of addressing these challenges (OECD, 2015). The net impact of a climatic shock on food security depends not only on the intensity of the shock but also on the vulnerability of the food system (and its subcomponents, the relationships between them) to the particular shock, *i.e*. the propensity or predisposition of the system to be adversely affected (IPCC, 2014).

According to the research report of the World Bank (2006), climate change, as a key global environmental hazard, is massively disrupting agricultural systems and food markets, posing population-wide risks to food supply, a threat that can be reduced by increasing the adaptive capacity of smallholder farmers as well as increasing resource use efficiency in agricultural systems (Lipper *et al.*, 2014). Climate change has the potential to significantly undermine future efforts to achieve food security and sustainably manage the natural resource base of agriculture. Rising temperatures, increased frequency and severity of extreme climatic events, and changes in the distribution, quantity and timing of rainfall projected over the course of this century could have strong negative impacts on crop and livestock production. These impacts will further compound the already substantial challenges facing agriculture, including increasing population pressure on the resource base, land degradation, loss of agricultural biodiversity, and damage from pests and diseases.

These negative effects from climate change are already being felt across the world particularly in food-insecure regions of Africa such as Ethiopia. Warming trends are projected to accelerate over the course of this century, and the frequency and intensity of extreme events are likely to increase. Similarly, increasing trends of temperature are observed in Ethiopia (Messay, *et al*, 2017). Regional shifts in precipitation patterns are projected to lead to an overall drying trend in some sub-tropical regions, such as southern Africa, the Mediterranean Basin, and southeastern Europe and Central America, and to increased rainfall in other regions, including North, South, and Southeast Asia and East Africa (Christensen *et al*., 2007).

Huntingford *et al.* (2005) indicates that wet years are projected to become wetter and dry years drier, while the frequency of extreme wet and dry years is expected to increase globally. On an annual (seasonal) time scale, the number of rainfall events is likely to decrease, while rainfall intensity is likely to increase due to greater atmospheric moisture retention with increased air temperatures. Potential manifestations of increased seasonal variability include more extreme hot days during the growing season, a shift in precipitation towards heavier but less frequent rainfall events, and longer periods between rains which, when coupled with increased rates of evapotranspiration under warmer temperatures, could negatively affect crop growth. Food security has re-emerged as a core development concern as extreme climate events, rising energy prices, low global food stocks, changing urban diets, and growth in bio-fuels converge to push up prices of basic commodities around the globe. Studies (Huntingford *et al.,* 2005; Christensen *et al*. 2007) indicate that climate change can further disrupt food production and bring uncertainty and volatility to food prices, with disproportionate effects on the world's poor countries such as Ethiopia.

Paradoxically, agriculture contributes about 20% of the greenhouse gases that causes climate change. The two most harmful greenhouse gases from agriculture are nitrous oxide from soils and methane from cattle, but carbon dioxide emission due to conversion of forests to crop land, is also important. On the other hand, agriculture has the potential to capture a significant part of the excess atmospheric carbon in the soil in the form of organic matter (Nelson, 2009). According to Temesgen, *et a.l* (2008), generally, increased frequency of droughts and floods are highly negatively affecting agricultural production, demonstrating agriculture's sensitivity to climate change.

2.3. Climate-smart agriculture *vs* conventional agriculture: A comparative overview

CSA was defined by FAO (2010) as agriculture that sustainably increases productivity, enhances resilience of livelihoods and ecosystems, reduces and/or removes greenhouse gases (GHGs) and enhances achievement of national food security and development goals.as indicated in FAO (1996),also indicate that the conventional agriculture is one of the most environmentally devastative economic activities at it involves clearing of forests, use of great amount of water, irrigation, and application of agro-chemicals.

Most literatures like Zeder (2008), indicate that agricultural practices started around 10,000 B. C though the dates of domesticated plants and animals vary with the regions. Agriculture, as art and/or science, managing the growth of plants and animals for human use, includes cultivation of the soil, growing and harvesting crops, breeding and raising livestock, dairying and forestry Nierenberg (2008).

Agriculture-environment relationship has been a locus of researches particularly owing to the impetus toward increased food production following World War II (1939-1945) as a result of a new population explosion (Mallick and Ghani, 2005). Consequently, green revolution, involving selective breeding of traditional crops for high yields, new hybrids and intensive cultivation methods adapted to the climates and cultural conditions of densely populated countries temporarily stemmed the pressure for more food FAO (2003). A worldwide shortage of petroleum in the mid-1970s, however, reduced the supplies of nitrogen fertilizer essential for the success of the new varieties. Simultaneously, erratic weather and natural disasters such as drought and floods reduced crop levels throughout the world. Famine became common in many parts of Africa south of the Sahara. Economic conditions, particularly uncontrolled inflation, threatened the food supplier and the consumer alike. These problems became the determinants of agricultural change and development UNEP (2011).

Various research findings and reports (UNECA, 2015; Temesgen, *et a.l.*, 2008) argue that the conventional agriculture must undergo a major transformation in the coming decades in order to meet the intertwined challenges of achieving food security, reducing poverty and responding to climate change without depletion of the natural resource base. Although agriculture appears to be large in the economy of Africa, employing more than 60% of the population and contributing 25-34% of the GDP, productivity is low and food insecurity is high. Particularly, food availability remains low in sub-Saharan Africa and slow progress has been achieved in improving access to food due to environmentally-unfriendly approaches, sluggish income growth, high poverty rates and poor rural infrastructure which hampers physical and distributional access. At the same time, the stability of food supplies has deteriorated owing to environmental degradation, political instability, civil wars and outbreaks of deadly diseases. As a result, one in four people remain malnourished in sub-Saharan Africa, a global region where Ethiopia is located. The region also faces challenges in food utilization as indicated by high prevalence of stunted and underweight children and in improving the dietary quality and diversity, particularly for the poor. Krawinkel (2005).

CSA is different from the common (conventional) agriculture in that it integrates all the dimensions of sustainable development: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change from the farm to national levels; and developing opportunities to reduce greenhouse gas emissions from agriculture compared with past trends. It is an approach to identify the most suitable strategies according to national and local priorities and conditions to meet these objectives. There is no such thing in conventional agricultural practices. An action plan for African agricultural transformation produced by UNECA (2015) indicates that whether or not a particular practice or production system is climate smart depends upon the particular local climatic, biophysical, socioeconomic and development context, which determines how far a particular practice or system can deliver on productivity increase, resilience and mitigation benefits. Unique circumstances to CSA are that ecosystem functions, including biodiversity and water services, are key to increasing resource efficiency and productivity and ensuring resilience. In CSA, ecosystem based adaptation has an important role to play in developing an agricultural sector that is well integrated to climate resilient practices to the broader landscape of the locale in environmentally and socially sustainable ways.

Therefore, CSA is very different from the 'business as usual' conventional long-practiced agriculture in that it is a solution to the challenge of achieving food security and economic development under a changing climate, focusing smallholder farmers at large. As stated in (IPCC, 2007) it moves beyond 'adaptation', that is, specific adjustments to actual or predicted climate changes, to building 'adaptive capacity', defined as 'the ability of a system to adjust to climate change'. Contrary to the conventional agriculture, CSA improves and support access to agricultural production for marginalized smallholders in a way that minimizes risk, promotes user-centered innovation that improves the adaptive capacity of smallholder and the agricultural systems; and facilitate sustainable use of the natural resource base to ensure the viability of continued production and adaptation (Sugden, 2015). In fact, integrating agro-ecological approaches into smallholder farming systems is not without challenges. For instance, new opportunities for private investment in low-external input systems must be identified in order to achieve the goals of CSA. And again diversifying crop production may alter workloads, potentially with gendered impacts; and capacity-building may be necessary to achieve more equitable market access for smallholders to achieving sustainable development and food security under a changing climate.

2.4.Actions and approaches to climate-smart agriculture

It is clearly discussed hereinbefore that CSA is an approach for transforming and reorienting agricultural systems to support food security under the new realities of global climate change. Widespread changes in rainfall and temperature patterns threaten agricultural production and increase the vulnerability of people dependent on agriculture for their livelihoods, which includes most of the world's poor. Threats can be reduced by increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems. Lipper (2014) states that CSA promotes coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways through four main action areas: (1) building evidence; (2) increasing local institutional effectiveness; (3) fostering coherence between climate and agricultural policies; and (4) linking climate and agricultural financing. CSA differs from 'business-as-usual' approaches by emphasizing the capacity to implement flexible, context-specific solutions, supported by innovative policy and financing actions.

Scherr (2012) indicates integrated landscape management is one of the approaches to implement climate-smart agriculture. According to *Eco-Agriculture Policy Focus Integrated Landscape Management* (ILM) is an increasingly popular approach to addressing development, climate change, food security and a host of other global issues. A *'landscape'* is a socio-ecological system that consists of a mosaic of natural and/or human-modified ecosystems, with a characteristic configuration of topography, vegetation, land use, and settlements that is influenced by the ecological, historical, economic and cultural processes and activities of the area. The mix of land cover and use types (landscape composition) usually includes agricultural lands, native vegetation, and human dwellings, villages and/or urban areas. The spatial arrangement of different land uses and cover types (landscape structure) and the norms and modalities of its governance contribute to the character of a landscape. Scherr (2012) indicates that integrated landscape management approaches support food production, ecosystem conservation, and rural livelihoods across entire landscapes. These are known under various terms including eco-agriculture, landscape restoration, territorial development, model forests, integrated watershed management, agro-forestry landscapes, and the ecosystem approach to managing agricultural systems, among many others.

According to Scherr (2012), integrated landscape management approaches have five elements in common. These are:

- ✓ Landscape interventions are designed to achieve multiple objectives, including human well-being, food and fiber production, climate change mitigation, and conservation of biodiversity and ecosystem services

- ✓ Ecological, social and economic interactions among different parts of the landscape are managed to seek positive synergies among interests and actors or reduce negative trade offs
- ✓ The key role of local communities and households as both producers and land stewards is acknowledged
- ✓ A long-term perspective is taken for sustainable development, adapting strategies as need to address dynamic social and economic changes
- ✓ Participatory processes of social learning and multi-stakeholder negotiation are institutionalized, including efforts to involve all parts of the community and ensure that the livelihoods of the most vulnerable people and groups are protected or enhanced

Scherr (2012) indicates that for agricultural systems to achieve climate-smart objectives, including improved food security and rural livelihoods as well as climate change adaptation and mitigation, they often need to be taken a landscape approach; they must become 'climate-smart landscapes'. Climate-smart landscapes operate on the principles of integrated landscape management, while explicitly incorporating adaptation and mitigation into their management objectives.

According to Negra (2014), integrated policy approach is another CSA approach to address the linked challenges of climate change, unsustainable agriculture and food insecurity. While concepts are still evolving, national policy implementation of CSA is generally seen to include the following elements.

- Integrated, context-specific assessment of drivers of unsustainability and greenhouse gas emissions,
- potential CSA interventions, with emphasis on identifying synergies (*e.g*. diversified production and income sources) and trade-offs (e.g. biodiversity *vs* food production), and major barriers to their implementation (e.g. weak information or legal systems);
- Strengthening institutions and infrastructure that promote sustainable practices in farming, forestry and fishing systems (e.g. cooperatives and community based initiatives),

- efficient, equitable food chains, and enhanced governance systems to manage common resources, strengthen land tenure, and improve ecosystem services; establishing a strategic framework for coordinating key actors (e.g. ministries, local governments, farmers, agribusinesses, international agencies) in development
- implementation of policy and market measures (e.g. credit and market access) and blended financing sources (e.g. climate and development funds; public and private sources) to incentivize CSA practices (e.g. appropriate inputs) and to reduce and respond to disaster risk (e.g. insurance; social protection);
- building capacity for information systems including research and development (e.g. varieties and breeds suitable for future climate and vulnerable populations), advisory services (including risk assessment), information technologies, and monitoring and evaluation.

Negra (2014) indicated that many existing national policy goals and public programs designed to increase agricultural production, improve livelihoods, and reduce environmental risks can become important pillars of a national CSA strategy. A review of pre-existing policies to identify necessary changes and investments is an important first step toward an integrated policy approach.

There is also a gender-responsive approach in CSA (Nelson and Huyer, 2016). The gender gap in agriculture is a pattern, documented worldwide, in which women have less access to productive resources, financial capital and to advisoryaaaaaaaa services compared to men in agriculture. In the context of Climate-Smart Agriculture (CSA), this gap means that men and women are not starting off on a level playing field. While gender shapes both men's and women's lives, the tendency is for women to have a more disadvantaged position in comparison to men. This can have significant implications for the adoption and sustainability of practices under a CSA approach. Further, there is a risk that, if this gap is not taken into consideration, the development of site-specific CSA options could reinforce existing inequalities.

In order to support women's and men's equal uptake of and benefit in site-specific CSA practices, gender analysis as well as equal participation and engagement of women and men are the key actions to be taken at the outset of any CSA intervention. In the longer term, broader changes are needed in order to reduce the constraints women and men may face in terms of accessing resources, services and information. Gender-sensitive indicators of the performance of a particular, CSA-sensitive practice include counts of the numbers of women and men engaged in testing or applying practices and/or long-term change. These changes include increased control of productive assets, participation in decision-making, knowledge, changes in behavior and attitude, awareness, empowerment, and improved economic status and food security and nutrition of women and men. Further, to be able to measure the gender dimensions of a CSA practice's performance, women need to be actively involved in defining indicators and in monitoring implementation and impacts (Nelson and Huyer, 2016).

2.5. Practices, adoption strategies and technologies in CSA among smallholders

According to FAO (2016), CSA includes proven practical techniques such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing and improved water management. It also involves innovative practices such as improved weather forecasting, early-warning systems and climate-risk insurance. CSA aims to get existing technologies off the shelf and into the hands of farmers, as well as to develop new technologies such as drought-tolerant or flood-tolerant crops to meet the demands of the changing climate.

Nyasimi, *et al.* (2017) indicates that smallholder farmers need information and knowledge on appropriate climate-smart agriculture (CSA) practices, technologies, and institutional innovations in order to effectively adapt to changing climatic conditions and cope with climate variability. Farmers may be exposed to various CSA technologies and institutional innovations for adaptation and risk management. These include crop breeding, soil and water management, tree and coffee nurseries, fish rearing, bee-keeping, and growing of fruits and vegetables. The institutional innovations include markets, value chains, input supply systems, savings and credit cooperatives, energy production and conservation (biogas, improved stoves, tree nursery), and community weather stations. Farmers may be trained in amateur filming and photographic skills and were provided with handheld flip cameras to document the learning process to enable sharing of their learning experiences with other farmers within their communities who did not participate in the learning journey.

In fact, as indicated by FAO (2012), between mitigation and adaptation, the latter is clearly the priority for less-developed countries (such as Ethiopia) or low income agricultural-based populations in any country where agricultural development for food security and poverty reduction are the main policy objective. In this context, mitigation is a secondary benefit, but one which is nonetheless important to consider since mitigation-related activities are often synergistic with sustainable development generally, and adaptation specifically. Such actions often involve increasing the efficiency of resource use, as well as the restoration and conservation of agro-ecosystems to improve resilience. The potential for financing such mitigation actions in developing countries goes well beyond carbon offsets, with several alternative financing alternatives linked to the Green Fund currently under discussion.

Nyasimi, *et al.* (2017) identified the following CSA particles, technologies and institutional innovations in Tanzania, undertaken by 15 farmers:

- ✓ Soil and water conservation practices by using traditional soil and water conservation technique), irrigation and terracing, early planting, intercropping, and minimum tillage;
- ✓ Forestry innovations and environmental conservation strategies through establishment and management of a tree nursery, fruit trees, agro-forestry trees, construction of terraces that are reinforced with drought tolerant fodder grasses strips, coffee seedling nurseries and bio-digesters;
- ✓ Cropping innovations and livelihood diversification through intensive cropping of cloves, black pepper, potato trials, avocado, and coffee varieties, a coffee nursery and bee-keeping;
- ✓ Improving access to finance through collective action through establishment of a savings and credit (SACCOS) group, a scheme that has enabled farmers to pool resources and bargain for better prices;

- ✓ Weather information services through a community managed weather station, where farmers collect climate data, which is then shared with the National Meteorological Agency (NMA). This community managed weather station raised the farmers' consciousness of the changing climate and the importance of integrating indigenous knowledge and scientific weather forecasts as well as develop strategies to support NMA to gather climate data from the local level.

Table 2.1: Benefits of CSA practices, technologies, and institutional innovations

CSA practices	**Activities**
Soil & water conservation agriculture	Promotes an integrated soil, water and nutrient management by retaining water and the use of crop residues to support the pits leads to improved and sustained soil fertility and crop productivity, reduced soil erosion, and enhanced soil carbon sequestration.
Small-scale Irrigation	Small-scale irrigation offers key opportunities for adaptation as water supplies dwindle and rainfall becomes more erratic. Through irrigation, farmers can diversify into high value vegetable production thus reducing risks of crops loss and increasing incomes
Terracing	Promotes soil and water conservation, especially on steep slopes to reduce soil erosion and increased water percolation. The terraces are reinforced with grass strips and agro-forestry trees (for timber and fruits), thus contributing to mitigation and increased incomes.
Traditional & scientific weather forecasts	Reduces risks associated with failed seasons or variable rainfall and enable farmers to make better farming decisions for improved productivity and risk management.
Agro-forestry	Establishment of deep root, drought tolerant leguminous trees that fix nitrogen and shade leaves during the rainy season, providing organic residues and nutrients. Contributes to carbon sequestration, reduced soil erosion and moisture stress, and tree products that are sold for income.
Biogas & use of efficient stoves	Reduces greenhouse gas emission by utilizing methane from cow dung to generate energy for household consumption. Replaces purchase of kerosene and harvesting of trees, thus saving families income. Bio-slurry is used as manure, hence increasing soil fertility. Efficient stoves are combustion and fuel-efficient and reduce particulate air pollution, cooking time and time spent acquiring firewood.
Composting	Composting of crop residues and organic domestic wastes is used for soil fertility and improve crop productivity. Also contributes to improved soil structure, moisture retention and reduced emissions from application of raw animal manure.
Crop rotation	A crop diversifying practice that is used to achieve crop diversity, reduce incidences of pest and diseases of particular crop, improves soil structure and soil fertility through nitrogen fixing crops and reduces soil erosion

Drought and diseases tolerant crop varieties	Adaptive crop varieties that are stress tolerance and disease resistance; early maturing to avoid crop loss from shorter growing seasons or unreliable rains. This leads to improved productivity and reduced risk of crop failure
Drought tolerant & deeper rooted fodder grasses & legumes	Contributes towards food security and increased livestock productivity. Use of improved fodders leads to reduction of emissions from enteric fermentation of livestock through improved digestion. Increased milk production and heavier anima weight leads to more income.
Early planting & early maturing crop varieties	Varieties that are more adapted to low and unreliable rains, and shortened growing seasons thus leading to reduced risk of crop failures.
Minimal tillage	Conserves soil moisture and control erosion through minimum soil disturbances. It improves crop productivity and reduces soil compaction thus reducing emission
Intercropping & crop diversification	Intercrop of legume and non-legume crop and trees contributes to nitrogen fixation, improved water retention, reduced crop failures to drought, pest and diseases. Leaves of trees intercrop are used as mulch and compost, thus contributing to above ground carbon sequestration.
Saving and credit services (SACS)	Offers safety nets to give farmers through stronger marketing power. SACS offers access to credit to farmers to start CSA practices such as irrigation and purchase of food during droughts.
Management of a tree nursery & tree planting	Trees nursery provide income. The planted trees increase soil fertility and can help control erosion, as well as provide fuel wood and timber, medicines and fruits. Trees can also store substantial amounts of carbon.
Livelihood diversification	Diversification of crops, livestock (bee-keeping), trees and irrigation is potential response to overcoming unreliable rainfall and drought. This will minimize weather-induced losses and stabilize incomes.

Source: Nyasimi, *et al.* (2017) and FAO (2016)

2.6. Climate change, CSA and food security nexus

Climate change, agriculture and food security are highly interlinked in both positive and negative ways. Climate change is already hampering agricultural growth by reducing food productivity and production and adds a layer of pressure to already fragile food production systems. Drought, flood and hurricanes, ocean acidification and increasing sea levels, has already reducing agricultural productivity putting people's lives at risk (WFP, 2012; UNFCCC, 2015). Livelihoods are also increasingly in jeopardy, as crops, livestock and fish resources and their ecosystems; agriculture, livestock and fishing infrastructure; as well as productive assets such as irrigation systems and livestock shelters are destroyed due to climate change-related extreme weather condition (FAO, 2015). This shows the fact that there are strong nexus between climate change, agricultural productivity and food security. While agriculture tends to support the overwhelming majority of the population in every part of the world, climate change is affecting all the four key dimensions of food security such as availability, accessibility, utilization and sustainability of the food supply. It is worth mentioning that CSA can be used for mitigating and adapting the impacts of projected climate change since CSA brings together practices, policies and institutions that are not necessarily new but are used in the context of the existing climatic changes in a given area. Furthermore, CSA addresses challenges faced by triple interplay of agriculture, food security and climate change holistically.

Climate change is leading to significant changes in agriculture and food security at the global and local level. Its impacts are both short-term, resulting from more frequent and more intense extreme weather events and long term, caused by changing temperatures and precipitation patterns (WFP, 2012). It is not possible to predict future climatic conditions with certainty, but the scientific consensus is that global land and sea temperatures are warming and will continue to warm regardless of human intervention for at least the next two decades, under the influence of greenhouse gases (GHGs). Climate change will affect agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts. Rising seas will lead to loss of territory and decline in agriculture affecting the 25% of global human populations who live in low-lying coastal areas. Especially vulnerable are drier nations such as Ethiopia and island nations in the Caribbean, Pacific and Indian Oceans, and river deltas of the Nile, Ganges and the Mekong where food production is heavily concentrated (Boto, *et al.*, 2012).

In 2007, the IPCC forecasted that global average temperatures could rise by 1.1°C to 6.4°C by the end of the 21st century (WFP, 2012). If the rise is at the lower end of the scale, the impact on agricultural systems may be modest; at the higher end however, it will almost certainly be disastrous. Even a 2°C rise by the end of this century (an optimistic scenario) will lead to dramatic changes in patterns of land use (WFP, 2012; Brevik, 2013).

Agriculture is at the nexus of three of the greatest challenges of the 21st century, achieving food security, adapting to climate change, and mitigating climate change while critical resources such as water, energy and land become increasingly scarce. Policymakers are therefore presented with a double challenge: to reduce agricultural emissions, and to help agriculture adapt to a changing climate. Agriculture is crucial for food security and rural incomes, as well as other essential products, including energy, fiber, feed and a range of eco-system services. Agriculture is a significant cause of climate change, directly responsible for some 12-14% of GHG emissions or 30% when considering land-use change, including deforestation driven by the agricultural expansion for food, fiber and fuel, which accounts for an additional 17% of emissions (WFP, 2012). At the same time, agriculture is also a victim of climate change, with farmers around the world already facing an uncertain future as a result of rising temperatures, changing patterns of rainfall and the shifting distribution of pests and diseases. Sustainable agriculture simultaneously increases production and income, adapts to climate change and reduces GHG emissions, while balancing crop, livestock, fisheries and agro-forestry systems, increasing resource use efficiency (including land and water), protecting the environment and maintaining ecosystem services (Boto, *et al*., 2012).

The adverse impact of climate change on agriculture affects more importantly the rural poor living in developing countries. The majority of the world's poorest and hungry live in rural settings and depends directly on agriculture. Over 70% of the world's poor live in rural areas. These 2.1 billion people live on less than US$2 a day. This is not inevitable, and an improved economic environment and greater social equity at local, national, and global scales have the potential to ensure that agriculture is able to provide improved livelihoods. Reducing poverty and securing food to world's population while reducing GHG emissions will require a combination of technical, political and financial factors that will make climate change the biggest challenge for mankind in human history (Boto, et al., 2012). This indicates the fact that raising agricultural productivity and incomes in the smallholder production sector is crucial for reducing poverty and achieving food security, as a key element and driver of economic transformation and growth, and within the broader context of urbanization and development of the non-farm sector (Philip, 2014). CSA identifies synergies and trade-offs among food security, adaptation and mitigation as a basis for informing and reorienting policy in response to climate change (Leslie et al, 2014). The overall aim of CSA is to support efforts from the local to global levels for sustainably using agricultural systems to achieve food and nutrition security for all people at all times, integrating necessary adaptation and capturing potential mitigation. Three objectives are defined for achieving this aim sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development; adapting and building resilience to climate change from the farm to national levels; and developing opportunities to reduce GHG emission. (Leslie et al, 2014).

CSA builds on existing experience and knowledge of sustainable agricultural development. Sustainable intensification is a cornerstone, as more efficient resource use contributes to adaptation and mitigation via effects on farm productivity and incomes as well as reduced emissions per unit of product. Sustainable intensification on existing agricultural land has major mitigation potential by reducing the conversion of forest and wetlands, although additional protection measures may be required. CSA emphasizes agricultural systems that utilize ecosystem services to support productivity, adaptation and mitigation. Examples comprise integrated crop, livestock, aquaculture and agro-forestry systems; improved pest, water and nutrient management; landscape approaches; improved grassland and forestry management; practices such as reduced tillage and use of diverse varieties and breeds; integrating trees into agricultural systems; restoring degraded lands; improving the efficiency of water and nitrogen fertilizer use; and manure management, including the use of anaerobic bio-digesters. Enhancing soil quality can generate production, adaptation and mitigation benefits by regulating carbon, oxygen and plant nutrient cycles, leading to enhanced resilience to drought and flooding, and to carbon sequestration. These supply-side changes need to be complemented by efforts to change consumption patterns, reduce waste, and create positive incentives along the production chain (Bruce et al, 2014).

2.7. Empirical studies on climate-smart agriculture in Ethiopia

The study by Ngigi (2009) and Lasco et al. (2014) indicates that smallholder farmers in Sub-Saharan African countries (SSA) are confronted with changing patterns of temperature and precipitation and increased occurrences of extreme events like droughts and floods. Meteorological data show a persistent upward trend in both mean temperatures and variation in seasonal and annual rainfall patterns. Changes in temperature and precipitation patterns will expose the region's agricultural production systems to tremendous risks, causing more short-term crop failures and long-term production declines.

Empirical studies measuring the economic impacts of climate change on agriculture (Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006; Mano and Nhemachena 2006; Benhin, 2006) suggest that such impacts can be significantly reduced through adaptation. It is particularly important to understand the vulnerability of farmers in Ethiopia, because around 85% of the population is farmers and climate change impacts are expected to be significant. Climate change in Ethiopia will not only increase rainfall variability and lead to more frequent droughts and higher risk of floods; it will also continue to intensify the degradation of soil fertility, which causes agricultural productivity to decline.

While individual climate-smart practices provide multiple benefits, there are complementarities and synergies when more than one practice is adopted together. For instance, in smallholder subsistence farming in much of SSA, one of the major sources of risk is moisture stress, where fertilizer will not be applied if application to a crop is perceived as too risky (Rockström et al. 2002). This happens because smallholder farmers are averse to risk, given their precarious financial situation and their poor access to credit and insurance. The risk of moisture stress is increasing as a result of increased variability of seasonal distribution of rainfall throughout most of Africa, coupled with a reduction in rainfall in much of the SSA (Lobell et al. 2008). Under these circumstances, agricultural water management can reduce the risk created by moisture stress and thus make farmers more confident about applying fertilizer.

For Ethiopia, a country that has a vision of building a climate-resilient economy, identifying a combination of climate smart practices that deliver the highest payoff is a valuable contribution to help government and development agencies design effective extension policies. In Ethiopia, where information is scarce and markets are ill-functioning, social networks are considered a means to facilitate the exchange of information, enable farmers to access inputs on schedule, and overcome credit constraints and shocks (Fafchamps and Minten 2002; Isham 2002). Particularly for smallholder farmers, local institutions play a pivotal role in building resilience and reducing vulnerability to climate change (Agrawal et al. 2009).

The results indicate that the current choices of alternative combinations of practices and related farm income in the Nile basin of Ethiopia are heavily influenced by climate. When the climate is hot and the rainfall is variable, farmers more often prefer a combination of practices over a practice in isolation. Adoption of fertilizer, whether alone or in combination with improved seed varieties, is less likely in areas of higher precipitation variability. However, under conditions of high rainfall variability, adoption of fertilizer and improved seeds are more likely when they are combined with agricultural water management practices.

An important message from the findings is that the observed changes in intensity and variability of rainfall in the Nile Basin of Ethiopia could have negative impacts on agriculture if these changes persist. However, there are opportunities for agricultural producers to improve their resilience in a changing world; agricultural water management is among the ways that producers in the region are presently adjusting management to improve production and to be ready for the possibility of a more challenging rainfall regime. Increasing water retention and improving infiltration of soils might become a greater priority for producers looking to capture and efficiently use scarce rainfall, in order to minimize the risks associated with adopting yield-enhancing inputs under conditions of extreme variability of rains and increasing temperature.

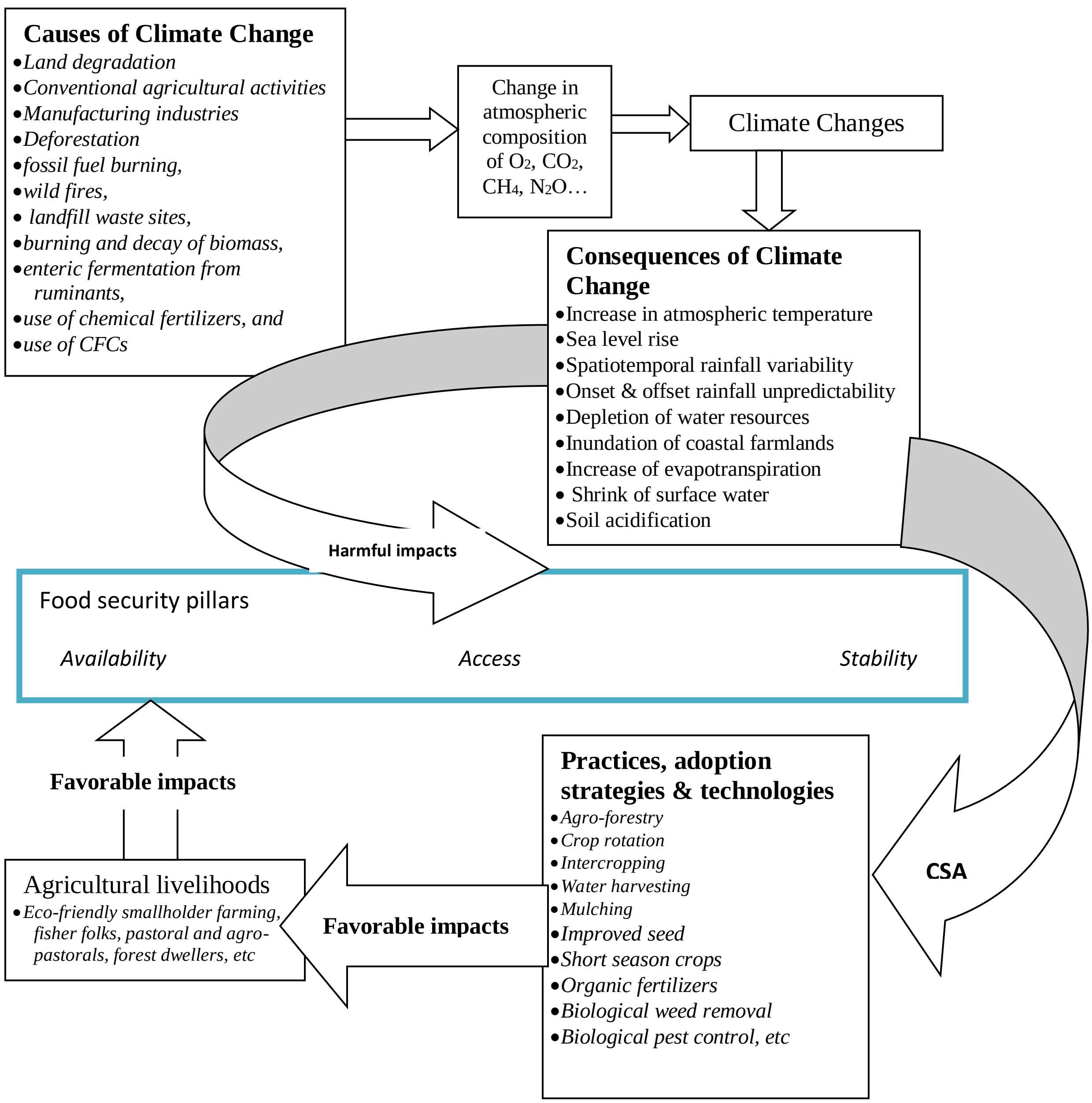
The study by (Kohlin, *etal,2018*) applied a multinomial endogenous switching regression approach by modeling combinations of practices and net farm income for each combination as depending on household and farm characteristics and on a set of climatic variables based on geo-referenced historical precipitation and temperature data. The sampling frame considered the traditional typology of agro-ecological zones in the country (i.e., *Dega* (cool, humid, highlands), *Weina-Dega* (temperate, cool subhumid, highlands), *Kolla* (warm, semi-arid lowlands), and *Bereha* (hot and hyper-arid)). The sampling frame selected the woredas1 in such a way that each class in the sample matched the proportions for each class in the entire Nile basin. Accordingly, a multistage sampling procedure was employed to select villages from each *woreda* and households from each village. First, 20 *woredas* from the five regional states were selected (three each from Tigray and Benshangul-Gumuz, six from Amhara, seven from Oromia, and one from SNNP). This resulted in a random selection of 50 farmers from each *woreda*, and, after cleaning inconsistent responses, a total of 929 farm households and 4702 farming plots. A primary result of this study is that farmers are less likely to adopt fertilizer (either alone or in combination with improved varieties) in areas of higher rainfall variability. However, even when there is high rainfall variability, farmers are more likely to adopt these two yield-increasing inputs when they choose to (and are able to) include the third part of the portfolio: agricultural water management. Net farm income responds positively to agricultural water management, improved crop variety and fertilizer when they are adopted in isolation as well as in combination. But this effect is greater when these practices are combined. Simulation results suggest that a warming temperature and decreased precipitation in future decades will make it less likely that farmers will adopt practices in isolation but more likely that they will adopt a combination of practices. Hence, a package approach rather than a piecemeal approach is needed to maximize the synergies implicit in various climate-smart practices.

2.8. Conceptual framework

The conceptual framework for this research is illustrated in the following Figure 2.1. The figure depicts that the causes of climate change are interconnected and various in number. These are land degradations, traditional farming practices, emissions from manufacturing industries, deforestation, fossil fuel burning, wild fires, landfill waste sites, burning and decay of biomass, enteric fermentation of ruminants, and use of chemical fertilizers. These activities result in changes in volume of atmospheric composition of oxygen, carbon dioxide, methane, water vapor and nitrous oxide which, in turn, implies to the changes in climatic conditions.

The conceptual framework also indicates that climate change results in several adverse socioeconomic and biophysical conditions such as increase in atmospheric temperature, rise in sea levels, spatiotemporal rainfall variability, unpredictability of onset and offset of rainfall, depletion of surface water resources, inundation of coastal farmlands, increase of evapotranspiration, shrinking of surface water resources, soil acidication, and prevalence of tropical disease and pests. As shown in the framework, the harmful impacts of these adverse factors are low availability, poor access, less utilization and unsustainable food supply. It further results in further impoverishments and sufferings which are often manifested in natural resource depletion, conflict, food shortage, fatality and forced migration. These changes can be resolved through proper implementation of climate smart agricultural practices, strategies and technologies which include, but not limited to, agro-forestry, crop rotation, intercropping, rainwater harvesting and mulching as well as application of short season crops, improved seed, organic fertilizers, biological weeds/pets controlling mechanisms. The conceptual framework depicts the fact that the favorable impacts of the eco-friendly climate smart agricultural practices benefit to improve the livelihoods of the farming community such as smallholders, fisher folks, pastoral and agro-pastorals, and forest dwellers. These, in turn, improves the fundamental food security pillars such availability of foods, access, utilization and sustainability of food supply.

Figure 2.1Cause and Consequence of Climate change and Favorable Impacts of Climate Smart Agriculture Practices



Source: Own construction based on empirical fieldwork data; FAO /2016/ and other literatures

CHAPTER THREE: DESCRIPTION OF THE STUDY AREA AND THE RESEARCH METHODS

3.1. Description of the Study Area

3.1.1. Location and size of Hidhabu Abote *Woreda*

Hidabu Abote *woreda* is one of the *woredas* in North Shewa Zone of Oromia Regional State. The *woreda's* capital is called Ejere town, which is 34kms (off the main AA-Bahr Dar road) away from the zonal capital Fiche town, and146kms from Addis Ababa.

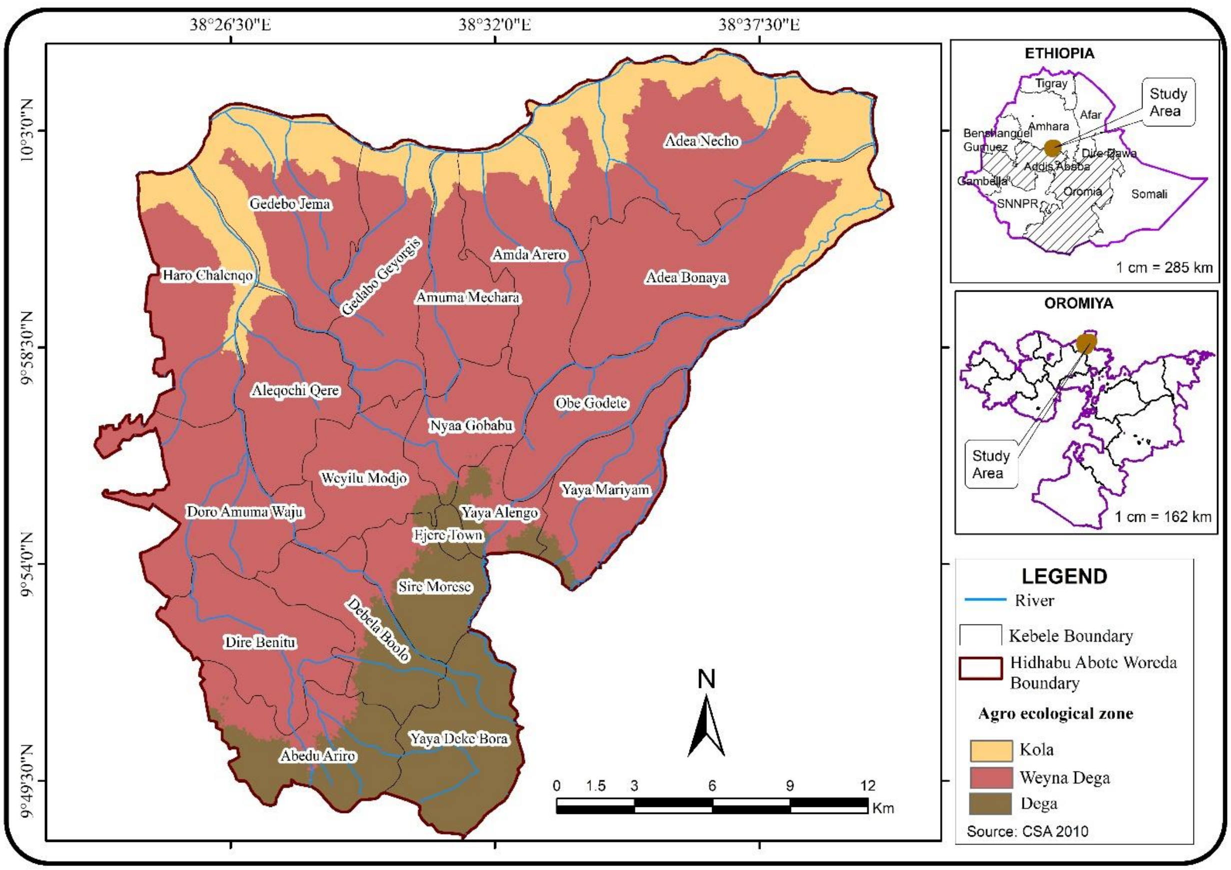


Figure 3.1: Ariel map of H/Abote Woreda and the three studied kebeles

The *woreda* is divided into 20 *kebeles* where 19 of them are rural *kebels* and one urban administrative unit (OBFED, 2011). Hidabu Abote *woreda* has proximity with Dera *woreda* in north,Wera Jarso in the west, Kuyu in the south and southwest and Degem in the northeast, east and southeast. The *woreda* has an astronomical location which extends from $8^{0}31'21''$ to $38^{0}36'34''$northwards and $9^{0}56'30''$ to $10^{0}01'34''$eastwards.

3.1.2. Demographic profile of H/Abote *Woreda*

H/Abote *woreda* is densely populated. According to population projection values of CSA (2013) at zonal and *woreda* levels, the total population of H/Abote *Woreda* in 2017 was 107,731 of which 54,475 (50.5%) were females and the remaining 53,276 (49.5%) male. Of the total population 97,427 (90.4%) were living in rural areas of the *woreda* their livelihoods being almost entirely dependent on agriculture. With this figure, the population density of the *woreda* is computed to be 213 persons per square kilometer which is by far greater than the national average (*i.e*. 90 persons per square kilometer).

No communities permanently live in the project area but it is used for livelihoods activities such as cultivation in cleared forest area, grazing land during the summer time, cutting for firewood, cutting grass for livestock fattening and breeding purposes. The social impact assessment showed that around 1769 people use the project area for these types of activities. In the surrounding project zone based on figures published by the Central Statistical Agency in 2005, Hidabu Abote *woreda* has an estimated total population of 89,863, of whom 45,278 are men and 44,585 are women. 3,556 or 3.96% of its population are urban dwellers, which is less than the Zone average of 9.5%. With an estimated area of 497.82 square kilometers, Hidabu Abote has an estimated population density of 180.5 people per square kilometer, which is greater than the Zone average of 143. The two largest ethnic groups reported in Hidabu Abote were the Oromo (97.53%), and the Amhara (2.37%); all other ethnic groups made up 0.1% of the population. Afan Oromo was spoken as a first language by 98.09%, and 1.87% spoke Amharic; the remaining 0.04% spoke all other primary languages reported. The majority of the inhabitants professed Ethiopian Orthodox Christianity, with 99.04% of the population reporting they practiced that belief.

As part of project preparation, a social impact assessment was conducted by World Vision Ethiopia in the concerned *woreda* which provided specific information about the communities' socio-economic conditions, vulnerability and other characteristics.

3.1.3. Agro-ecology and drainage

The total area of the *woreda* is about 50,596 hectares (505.96 square kilometers) of which about 6,939 hectares (13.7%) is *dega*, 36,368 hectares (71.9%) is *woinadega*, and the remaining 7,290 (13.7%) is *qola* agro-ecological zone.

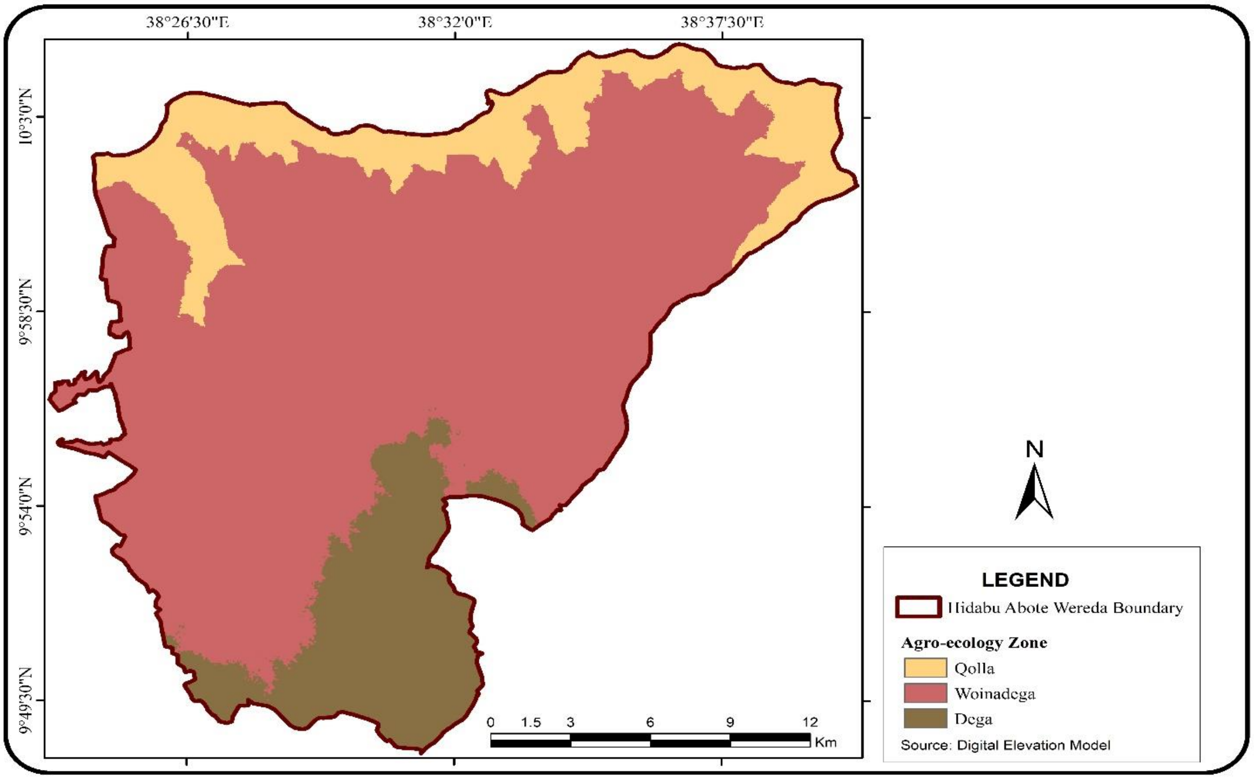


Figure 3.2: Relief structure of Hidhabu Abote *woreda*

According to Hurni (1998), *qolla* (tropical: *gamojji* in Afan Oromo) refers to lowlands between 500m and 1,500m. Valleys found in Jemma and Wonchit Rivers are grouped into this climate type and accounts for about 14.4% of the total. W*oina dega* (sub-tropical*: bad-dare* in Afan Oromo) is the midlands between 1,500m and 2,300m and *dega* (temperate: *badda* in Afan Oromo) lies between 2,300m and 3,200m above mean sea level (amsl). The predominant crops in *qolla* part of Hidhabu Abote are found to be sorghum, finger millet, sesame, cowpeas and groundnuts; while wheat, *teff*, barley, maize, sorghum, chickpeas and haricot beans are dominantly found in *woina dega* parts. Barley, pulses, wheat and nug crops dominate dega part of the *woreda*

The field observation across the *woreda* has given the researcher to have a glance at the fact that the *woreda* is more or less midland with plain topography. In fact, there are some mountain picks, hills, rivers and streams. Some of the mountain picks in the *woreda* areDhakabora, Siremorise, Garmojo, Debela, and Gar Cherkos. There are valleys like Jema in the northern part of the *woreda*. Plateaus and minor hills of varied heights are found across the *woreda*. The highest elevation is 3,003 meter while the lowest elevation is about 1,108 meters. Aleltu Tina, Aleltu Guda, Jema and Indris are the major rivers, while springs like Chafe Wuchale, Mumicha, Kile and Joro are providing the community with water serving both humans and the livestock together with smaller streams/tributaries like Horte, Bedas, Kewe and Hefiare.

3.1.4. Climatic conditions

According to key informant farmers, Das and *woreda*-level experts, Hidabu Abote *woreda* gets most of the rainfall in summer (June, July & August); winter (December, January & February) is the driest season. The highland areas get adequate rainfall while areas facing the Jemma river valley and receives a smaller amour. In general, it can be said that the *woreda* has adequate rainfall distribution. Thus it is conducive for different types of vegetation growth and agricultural activities. The two important rainy season lies between the period from mid-March to the end of April (spring rain or short rainy season, known as *Afrasa* in Afan Oromo) and between the period from mid-June to mid-September (summer rain or main rainy season, locally known as *ganna*).

Table 3.1: Long-term annual and season average total rainfall in H/Abote *Woreda (1983 – 2016)*

Seasons	Average total rainfall in mm	%
Autumn (September, October & November)	174.45	16.5
Winter (December, January & February)	29.55	2.5
Spring (March, April & May)	162.45	13.6
Summer (June, July & August)	829.85	69.4
Total annual	**1,196.30**	**100.0**

Source: Computed based on grid meteorological raw data from NMA

The long-term grid meteorological data (1983 to 2016) obtained from NMA of Ethiopia indicates that the area gets most of the rainfall amount (about 69.4%) in summer. The long-term annual total rainfall is computed to be about 1,196mm, the rainiest months being July and August (Figure 3.1). The *woreda* gets about 16.5% of the rainfall in autumn season; while 13.6% in spring season. The key informants indicate that sometimes the summer rain lasts for five months (June to October); while sometimes it rains only for two months (July and August). Spring rain is also very variable. Sometimes it rains throughout the whole season (March, April and May); while sometimes no rain for the entire season. The informants indicate that the number of rainy days within a year varies from place to place and this number slightly decreases as one goes down to the lowlands towards Jema Valley in the northern part of the *woreda*.

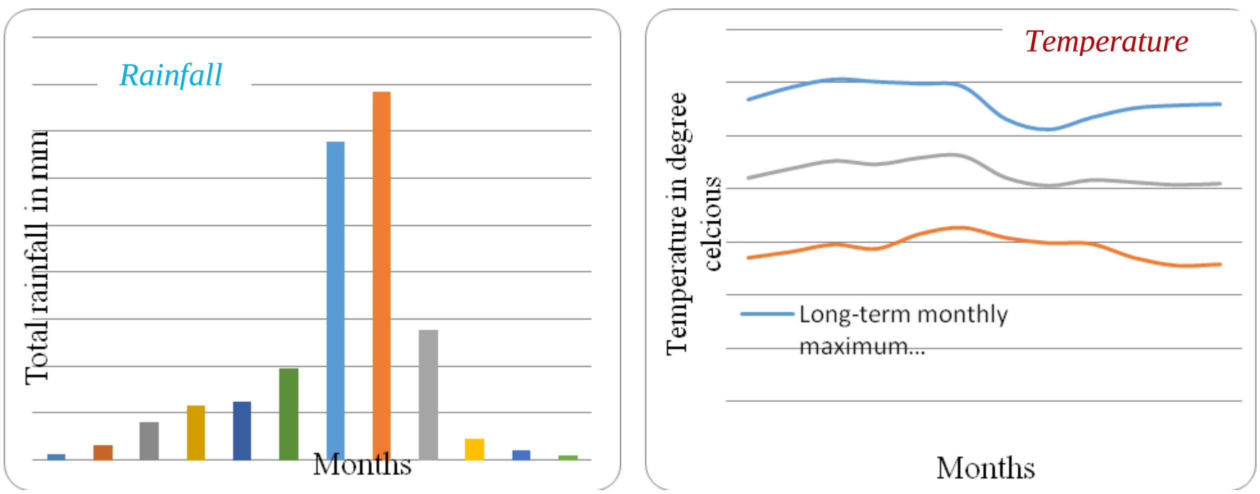


Figure 3.3: Long-term average monthly total rainfall and average monthly temperature in H/Abote *woreda*. (*Source:* Computed based on grid meteorological raw data from NMA)

Regarding temperature conditions, the long-term annual maximum temperature is computed to be 28.4°C, the annual average minimum temperature is 14.5°C and the average of the two is found to be 21.4°C (Figure 3.3). Based on traditional classification, the *woreda* is divided into three major agro-climatic zones: *dega*, *woinadega* and *qolla*.

3.1.5. Soil resources

There are two major types of soils in H/Abote *woreda*. These are red soil (locally known as biyye dima) and verisols (locally known as biyye guracha). The key informants are of the same mind that red soil is less fertile as compared to vertisoils. It is suitable for growing crops such as *teff*, wheat, maize, barley, peas, beans and sorghum. It has a good drainage and gives good yield with fertilizers. It is moderately susceptible to erosion. According to OBFED (2011) red soil covers about 35% of the total area of the *woreda*. Vertisoils are mostly found on flat areas. An expert working for the *woreda* Rural Land Administration and Use Office explained that it has got high percentage of organic matter. It has no as such water logging problem. It is suitable for growing crops such as *teff*, vetch and chickpeas. This type of soil covers about 51% of the total area of the *woreda*.

Soil types other than red soils and vertisoils are mostly found in the lowlands areas. According to the interview made with DAs and experts working for *woreda* agricultural bureaus, it is difficult to classify the soils in lowlands since they are found mixed. They are not as such suitable for agriculture. Such type of soils covers about14%of the total area of the *woreda*. According to the data obtained from the *woreda's* Bureau of Agriculture, farmers of the area mostly apply chemical fertilizers, animal manure and crop rotation practices to maintain the soil fertility. Some traditional environmental protection mechanisms, such as check dams and loss stone are also applied to protect soil loss.

3.1.6. Vegetation and wildlife resources

The field observation across the *woreda* has given the researcher to have a glance the poor vegetation covers of the *woreda*. In fact, OBFED (2011) also indicated that the vegetation cover of Hidhabu Abote *woreda* is poor. Only remnants of indigenous trees are found scattered on farm lands and around churches. Eucalyptus tree species are seen around homesteads. An interview data with the *woreda* Rural Land Administration and Use Office indicate that it was after the downfall of *dreg* regime that trees on communal land have been destroyed. The data obtained from Environmental Protection, Forest and Climate Change Authority Office of the *woreda* shows that currently there are about seven community conserved vegetation areas covering about 5,661 hectares in the *woreda*.

The study by World Vision-Ethiopia (2013) also confirms that Hidhabu Abote area is largely devoid of its natural vegetation because of continued deforestation for agriculture and wood extraction. According to the interview with an expert in the *woreda* Rural Land Administration and Use Office, encroachment of steep slopes, severe soil erosion, overgrazing and absence of conservation measures have reduced productivity, hampered the regeneration potential and threatened plants and animal species in the site. Land degradation in the *woreda* has become severe in the last 44 years, following the issuance of the forest land to individuals after the fall of regime of Haile Selassie I. High population growth, cultivation of steep slopes, high demand for wood and farm implements, and absence of soil and water conservation practices have exposed the area to greater risk of ecological disintegration.

According to the interview with an expert in the Environmental Protection, Forest and Climate Change Authority Office of the *woreda*, the major wild animals found in the *woreda* are hyena, leopard, baboon, duiker, porcupine, rabbit, bush back, warthog and the like. These are mostly found in valleys and in the low land parts of the *woreda.*

3.1.7. Agriculture and land use

Rain-fed agriculture is the dominant feature of the economy of the *woreda* as most rural areas in Ethiopia. Majority of the rural households and some of the urban population of the *woreda* obtain their income and food items from agriculture. The diversified nature of the *woreda's* climate seems favorable for both the production of crops and rising of livestock. Even though, such a good climate prevails, the output obtained from it is very low because of unreliable rainfall, poor agricultural practices and low usage of agricultural inputs. Currently, however, the agricultural sector is showing a significant improvement due to better extension services and the provision of somehow adequate inputs.

An interview data from the *woreda* bureau of agriculture indicates that the area is moderately productive and self-sufficient in food crops. Crop production is almost entirely rain-fed and mostly meant for household consumption. In fact, teff and wheat are produced for sale. Cash crops like niger seed and line seed are produced in small amounts. The method used to prepare land is ox-plow. Teff requires the most labor during land preparation, weeding and harvesting. The middle and better-off employ the very poor and poor households during land preparation, weeding and harvesting time. Weeding is usually done by men and women but land preparation and harvesting are done only by men.

According to the data obtained from the woreda bureau of agriculture, approximately land area of H/Abote *woreda* is 50,596 hectares, of which 67% is under crops, 4% is used for grazing, 27.5% is under forest and shrub, 0.8% is bare land. H/Abote *woreda* produces crops such as maize (*Zea mays*), sorghum (*Sorghum bicolor*), teff (*Eragostis tef*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), horse beans (*Vicia faba*), field peas (*Pisum sativum*), Vetch (Vicia sativa), chick peas (Cicer arietinum), lentils (Lens culinaris), linseed (*Linum usitatissimum*), niger seed (*Guizotia abissinica*), rape seed (*Brassica napus*). Fruits and vegetables production also practiced in the area. From annual crops cereals are the largest in production and area coverage followed by pulses and oil crops. Among cereal crops teff is the most highly produced crop followed by sorghum.

The data obtained from the *woreda* bureau of agriculture indicates that about 834,014 quintals of cereals (teff, wheat, barley, horse beans, maize, sorghum, field peas and chick peas) was produced in 2017/18 crop year. Teff 267,655 quintals (32%), sorghum 248,519 quintals (30%) and wheat 177,367 quintals (21%) are the three most dominant crops in the area.

The main types of livestock are cattle, sheep, goats, poultry, donkeys, horse and mules. Cows are the only animals that are milked. Livestock products such as butter, skin and eggs are sold for household income. Oxen and milking cows are mostly replaced from within the herd. The common challenges to the livestock sector are lack of feed, water and diseases. The animals feed on grazing land which is very scarce. The most common animal diseases are foot and mouth diseases, ovine pasteurellosis, bovine pasteurellosis, Peste des Petits Ruminants /PPR/ (known as sheep and goat plague), Newcastle disease /an infection of domestic poultry with virulent Newcastle disease virus (NDV)/, sheep and goat pox (a contagious viral skin disease of sheep and goats), and Lumpy skin disease (LSD/ (an infectious disease in cattle caused by a virus).

3.2. Research methods

Hidhabu Abote *woreda* is one of the 14 *woredas* of North Shewa zone, Oromia National Regional State (ONRS). According to the data obtained from the *Woreda* Administration Office, there are 19 rural kebeles and one urban center (Ejere town) in the *woreda*.

3.2.1. Research design

This research employed retrospective-cross-sectional study design as it was take in to account long-term climatic and the one-time socioeconomic data.

3.2.2. Sampling technique and sample size determination

Hidhabu Abote *woreda* is one of the 14 *woredas* of North Shewa zone, Oromia National Regional State (ONRS). According to the data obtained from the *woreda* administration office, there are 19 rural *kebeles* and one urban center (Ejere town) in the *woreda*. The study is apply multistage sampling technique. The sample *kebeles* in the district would be stratified based on their existing agro-ecological zones. Then purposive sampling technique was employed to select 3 rural *kebeles* from the total 19 rural *kebeles* in the *woreda*. This ensures most representation stratum than the total population and results in more reliable and detailed information. These *kebeles* are Yaya Dekebora,Weyilu Modjo,Gedebo Jema. The sample *kebeles* are CASCAPE (Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia) implementation areas and again they are more cereal productive *kebeles* according to the data obtained from the *woreda* agricultural office.

According to the information obtained from Hidhabu Abote *Woreda* Administration Office (HAWAO), the total number of farming households in the three sample *kebeles* is **2,254**. Then the number of sample households (the number of respondents for the household questionnaire survey) was determined to be about 200 (15.27% of the total households in the three *kebeles*) households with ±7% precision level and 95% confidence interval according to **Israel (2012)'s established table sample for sample size determination**. The total sample size has been distributed to each sample *kebele* based on the proportion of total number of households in each selected *kebele*. (See Table 1)

Table 3.2.: Sample kebeles and households by agro-ecology

Sample *kebeles*	Agro-ecology	Registered rural households	Sample households	% of Sample households
Yaya Dekebora	*Dega*	853	76	38
Weyilu Modjo	*Woinadega*	855	76	38
Gedebo Jema	*Qolla*	546	48	24

Total	--	2,254	200	100

Source: Organized based on the data obtained from *woreda* and *kebele* administrations

3.2.3. Tools and techniques of data

The research employed household questionnaire survey, key informant interviews (KIIs) and field observation in primary data collection.

a) Questionnaire survey

Questionnaire-based survey was administered to sample farming households by using a questionnaire survey after obtaining the consent of the respondents as a research ethics. The questionnaire was translated in to *Afan* Oromo for the purpose of simplicity and ease of communication between the enumerators and the respondents. With this technique data related to demography, socioeconomic, biophysical, farming practices and productivity, technology selection and adoption was collected. In order to maintain the quality of data, scientific principles and guidelines during questionnaire designing, data collection, data filling, encoding, data entry and processing was applied. Data collectors were oriented on issues related to data collection procedures and ethics. Pilot study was undertaken for pre-testing the questionnaire in order to estimate the time needed to complete and implement it. The questionnaire would be edited in the light of the results of the pilot study. Computer-based data cleaning was carried to check for the completeness, consistency and accuracy of data and to identify errors that may occur during data collection or coding process.

b) Key informant interview (KII)

In addition to the cross-sectional survey, some key persons in sample *kebeles* and the *woreda* were interviewed to obtain relevant information. The in-depth interview was focus on organizing formal interview with the aim of facilitating open interaction between the key informant and the researcher through inviting key figures in the respective institutions relevant for the issue under discussion to participate in open dialogue forum. The KII was done face-to-face. Key informant interview would be carried out with experts and administrators at *woreda* and kebele levels as well as the farmers, development agents and local NGO operating in the area.

c) Field observation

In addition to the above data collection methods, a field visit was executed by the researcher to substantiate and augment the information obtained through other primary and secondary data collection tools. Biophysical and socioeconomic conditions of the area would be explored through the field observation. In the meantime, experts and administrators in the *woreda* and *kebeles* would be briefly interviewed**.**

d) Secondary data sources

Besides the aforementioned data collection techniques and procedures, intensive desk review of published and unpublished literatures such as books, journals, articles, reports and e-resources would be carried out. Documents from various Oromia bureaus, Ministry of Agriculture, Websites of BENEFIT (Partnership to Promote Food Production, Income and Trade) and CASCAPE (Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia), Central Statistical Agency (CSA), National Metrological Agency (NMA) and Environmental Protection Agency would be reviewed.

3.2.4. Techniques of data analysis

Quantitative data, was collected from questionnaire survey and secondary data sources, was analyzed using latest version SPSS software and excel in order to describing key findings, conditions, states and circumstances disclosed from the data. Measure of central tendencies (mean), and measures of dispersion (standard deviation) were major descriptive techniques that are used to summarize and compare the data.

a) Analysis of climatic and agricultural production data

Investigating food security status of a community can be a very complex analysis that needs to be treated with a combination of different cross-sectional and longitudinal techniques (Maxwell *et.al*, 2003). This is mainly because, food security issue is characterized by multifaceted and intertwined issues such as agro-climatic and environmental circumstances, adaptation strategies, natural resource-base, food availability and access, and consumption patterns. In light of this, this section attempts to highlight detailed accounts of methods involved in data generation and analysis, including the study design, sampling procedures, instrumentation, reliability and validity of instruments and methods, and data analysis techniques.

Table 3.3: Techniques and indicators of data analysis

No	Techniques of analysis	Indicators
1	Household Food Balance Analysis (HFBA)	Availability and consumption component of food security
2	Household Food Insecurity Access Scale (HFIAS)	Access component of food security
3	Analysis of long-term weather and environmental conditions	Stability/sustainability component of food security

Investigating the interrelation between climate and agricultural production is a very complex analysis that needs to be treated with a combination of different intertwined issues such as agro-climatic and environmental circumstances. Hence, long-term climate and crop production data would have used for analytical purposes in the paper. The meteorological station located in the town of Ejere (capital of Hidhabu Abote *Woreda*) is considered to be representing the sample kebeles as it is located almost at the center of the *woreda*. This is used to look into the historical climatic constraints to agricultural productivity by seriously observing the correlation between climate elements and major crop outputs, the dynamic relationship between historic and current climatic variability and agricultural production as well as livelihood systems and coping strategies across the *woreda*. The latter component of the method provides a forum for exchange of ideas and prioritization of adaptation options that are relevant for the context of the area.

The analysis of climatic condition was involving the use of various mathematical procedures and techniques. Some of the analyses used to find solutions to varied mathematical problems such as long-term monthly, seasonal and annual mean values, precipitation concentration index (PCI) and coefficient of rainfall variability. Precipitation concentration index (PCI) is computed to look in to the level of rainfall distribution (concentration or uniformity) throughout months of a year. Precipitation concentration index (PCI) is computed to look into the level of rainfall distribution (concentration or uniformity) throughout months of a year.

The PCI values are calculated as follows, as in Messay (2012) and Mahlet (2013):

$$PCI = 100 \; x \; \frac{(\sum P_i^2)}{(\sum P_i)^2}$$

Where, $P_i =$ is the rainfall amount of the i^{th} month of a year

In this analysis, PCI values that are less than 10 indicate uniform monthly distribution of rainfall, while values between 11 and 20 indicate high concentration, and those above 21 indicate very high temporal rainfall concentration **a**s in indicated in Woldeamlak (2009), Messay (2012) & Mahlet (2013). Rainfall variability over a period of time was also analyzed by calculating the coefficients of variability (CV) of the rainfall values at different time scale. The CV of annual and monthly rainfall for each station was calculated by using individual year's rainfall (x_i) as follows (Agrawal, 2006):

$$CV = \frac{\frac{\sqrt{\sum f(x_i - \bar{x})^2}}{n}}{\bar{x}}$$

Where $\bar{x}$: Mean annual rainfall in mm

n : number of years for which the rainfall data are available for a given station

x_i : annual rainfall (mm) of the year i of a given station

b) Multivariate logistic regression model

Multivariate logistic regression technique is employed to analyze the nature and level of the determinants of determinants of indicators of CSA. The explanation and justification of the variables and unit of analysis is given hereunder.

i. **Mulching:** means covering the soil between crop rows or around trees with a layer of loose material such as dry grass, straw, crop residues, leaves, manure or compost. This helps to retain soil moisture by limiting evaporation, suppressing weed growth and enhancing soil structure, reducing runoff, protecting the soil from splash erosion and limiting the formation of crust. In addition, mulching reduces fluctuations in soil temperature which improves conditions for microorganisms. It is commonly used in areas affected by drought and weed infestation. However, improper mulching materials and practices may have little, or even negative, impact on the trees in your landscape. It is defined as the amount of production of crop and crop products of the household. One of the primary objectives of using mulching practice is increasing the production of crop products in the household. The crop product is measured in quintal per year per household or individual. The crop product also measured in amount of birr because it determines by the income that come from sale of crop products. The production of crop products is considered as indicator of source of income and dietary diversity of the households. Thus, it hypothesized as improved mulching technology adoption would have a positive impact on production of adopter households. In this research mulching is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

ii. **Crop rotation:** Crop rotation can be defined as a regular recurrent succession of different crops on the same land through a considerable period of years according to a define plan. The combination of quantitative and qualitative information to design crop rotations is the most common method in recent years. It is defined as the amount of production of crop and crop products of the household. The objectives of using crop rotation practice is increasing the production and productivity of agricultural products in the household. Thus, it hypothesized as improved crop rotation technology adoption would have a positive impact on production of adopter households. In this research crop rotation is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

iii. **Intercropping:** Intercropping is the growing of two or more crops in proximity to promote interaction between them and the planting of more than one crop on the same land at the same time. One of the advantages of intercropping system is its efficient and complete use of growth resources such as solar energy, soil nutrients, and water. Intercrops are most productive when their component crops differ greatly in growth duration so that their maximum requirements for growth resources occur at different times. In this research crop rotation is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

iv. **Agro forestry:** a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit. Agro forestry is also a means of optimal usage of land to produce for man's needs while at the same time maintain soil fertility status by sheltering the soil from direct sunrays. It also provides animal wastes which enrich the soil. In this research crop rotation is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

v. **Minimum tillage:** also called conservation tillage or zero tillage is a soil conservation system like Strip-till with the goal of minimum soil manipulation necessary for a successful crop production. It is a tillage method that does not turn the soil over. It is contrary to intensive tillage, which changes the soil structure using ploughs. The most important advantage of minimum tillage is that crops can be sown almost immediately the previous crop has been harvested and commonly approaching the optimum sowing time this is not possible with conventional tillage as that is time consuming. So it is highly suited to areas where two or more crops are rotated on the same land within the year. In this research crop rotation is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

vi. **Water harvesting:** is gather water from an area termed the catchment area and channel it to the cropping area where ever it is required. To use make more efficient use of the available water, it is important to consider how crops receive or loss water. Crops receive water through rainfall, irrigation, and stored soil water. They loss it through runoff, evaporation and drainage. some key principles on effective water management are use rain water effectively, make effective use of soil water reserves, take measure to avoid runoff, avoid wasting water through evaporation, reduce water losses through drainage. In this research Water harvesting is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

vii. **Composting:** Composting is the controlled aerobic biological decomposition of organic matter into a stable, humus like product called compost. It is essentially the same process as natural decomposition except that it is enhanced and accelerated by mixing organic waste with other ingredients to optimize microbial growth. The potential benefits of composting manure and other organic wastes are improved manure handling; reduced odor, fly, and other vector problems; and reduced weed seeds and pathogens. Land applied compost improves soil fertility, and water holding capacity. It is also free of offensive odors and can be stored for extended periods. These qualities make it suitable for use on the farm or for sale. Composting is easily adapted to agricultural operations because farms generally produce suitable amounts and types of waste for composting, have adequate land, would benefit from the application of compost to the soil, and have the necessary equipment already available. In this research composting is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

viii. **Improved seed:** Improved seeds are most commonly described as a technology to increase yields, a reductionist description that ignores the nexus of relations of the seeds. Seed is a key input for improving crop production and productivity. Increasing the quality of seeds can increase the yield potential of the crop by significant folds and thus, is one of the most economical and efficient inputs to agricultural development. Seed systems are composed of set of dynamic interaction between seed supply and demand, resulting in farm level utilization of seed and thus plant genetic resource. The seed system is essentially the economic and social mechanism by which farmers' demand for seed and various traits they provide met by various possible sources of supply. In this research improved seed is a dummy variable that took the value of 1 if the household applied mulching as CSA practice and 0 otherwise.

Table 3.4: CSA indicators and determinants of indicators of CSA

IVs (Determinants of CSA practices)	**DVs (CSA indicators)**
✓ $X_{1:}$ Sex of household head (0: male, 1: female)	Mulching (0: no, 1: yes)
✓ $X_{2:}$ Age of household head	Intercropping (0: no, 1: yes)
✓ $X_{3:}$ Family size	Agro-forestry (0: no, 1: yes)
✓ $X_{4:}$ Educational status of household head in grades	Crop rotation (0: no, 1: yes)
✓ $X_{5:}$ Access to rural credit service (0: no, 1: yes)	Compost (0: no, 1: yes)
✓ $X_{6:}$ Access to PSNP (0: no, 1: yes)	Water harvesting (0:no,1:yes)
✓ X_7 Firewood sale	Improved seed (0:no,1: yes)
✓ $X_{8:}$ Charcoal sale	Minimum tillage(0:no,1: yes)
✓ $X_{9:}$ Number of individuals engaged in off-farm income activities	
✓ $X_{10:}$ Number of oxen per household	
✓ $X_{11:}$ Access to irrigation (0: no, 1: yes)	
✓ $X_{12:}$ chemical fertilizer input per hectare per year	

- ✓ X_{13}: Per capita landholding size in hectare
- ✓ X_{14}: Average distance from farmland in km
- ✓ X_{15}: Access to extension service (0: no, 1: yes)
- ✓ X_{16}: : Number of crops used
- ✓ X_{17} Amount of crop production in quintals per year
- ✓ X_{18}: Income from remittance per year
- ✓ X_{19}: Income from livestock and livestock products sale per year
- ✓ X_{20}: Income from crop sale per year
- ✓ X_{21}: Farm land size
- ✓ X_{22}: Experience in farming
- ✓ X_{23}: Distance form market area
- ✓ X_{24}: Average number of field days
- ✓ X_{25}: Agro-ecology
- ✓ X_{26}: Income
- ✓ X_{27}: Frequency of visit of extension agents
- ✓ X_{28}: Access to weather information
- ✓ X_{29}: Slope of the farm land
- ✓ X_{29}: level of fertility of the farmland
- ✓ X_{30}: improved seed input per hectare per year
- ✓ X_{31}: severity of the climate problem
- ✓ X_{32}: Awareness of climate smart agriculture
- ✓ X_{33}: information/training on how to use climate smart agriculture
- ✓ X_{34}: Average distance from main farmland

The Variables

The dependent variables (Ys) selected for this analysis are indicators of CSA such as mulching, intercropping, agro-forestry, crop rotation, and compost. Likewise, 34 independent (explanatory) variables (X_1-X_{21}) that are supposed to determine household's daily per capita food availability were selected based on the preliminary survey for this study. Test of linearity, normality, homoscedasticity, autocorolality and multicollinearity would be problems, and transformed into natural logarism function.

c) Household Food Balance Model: Food consumption and availability component

A modified form of a simple equation termed as Household Food Balance Model, originally adapted by Degefa (1996) from FAO Regional Food Balance Model and thenceforth used by different researchers in this field (Messay, 2012) it was employed to compute the net quantity of per capita food. The net available food per household, as reported from household recall, was converted into dietary energy equivalent using EHNRI/FAO (1998)'s Food Composition Table for Use in Ethiopia. Then, the medically recommended level of calorie per adult equivalent (2100kcal/day/person for Ethiopia) was used as a cut-off point for food insecure and food secure resettler households (sample households). However, intra-household variations or individual issues were not treated since the unit of analysis for this study is household level. This model fails to demonstrate variations within the household, which in reality varies per age, sex, health status, and job category.

A modified household food balance equation employed in this analysis is:

NGA = (GP + GB + FA + GG + CC + MP + DP) - (HL+ GU + GS +GV)

Where,

NGA = Net grain available (quintal/household/year)

GP = Total grain production (quintal/household/year)

GB = Total grain bought (quintal/household/year)

FA = Quantity of food aid obtained (quintal/household/year)

GG = Total grain obtained through gift or remittance (quintal/household/year)

MP = Meat, meat based products and poultry (kilogram/household/year)

DP = Dairy and dairy based products ((kilogram/household/year)

HL = Post harvest losses due to grain pests, disasters, thievery, etc (quintal/household/year)

GU = Quantity of grain reserved for seed (quintal/household/year)

GS = Amount of grain sold (quintal/household/year)

GV = Grain given to others within a year(quintal/household/year)

d) Household Food Insecurity Access Scale (HFIAS): Food access component

The recent version of Household Food Insecurity Access Scale (HFIAS) is one of the most crucial techniques used in the investigation of the resettler households' food security status in this study area. It was a key technique for the investigation of the access component of food security in particular. HFIAS is one of the most up-to-date, relatively simple to run and methodologically rigorous (Swindale and Bilinsky, 2006) measure of food insecurity. The validity and reliability of the HFIAS in food security analysis have been tested by different researchers in different rural parts of the world (Coates *et.al*, 2003; Edward & Nanama, 2004; Knueppel *et. al*, 2009). In this study, HFIAS technique would be employed to classify the households into food secure and food insecure groups. Moreover, it would be used to assess the Household Food Insecurity Access Prevalence (HFIAP) and then to classify the food insecure ones further into mildly, moderately and severely food insecure households. A modified form of HFIAS's Sampling Guide, Generic Questions, and Key Informant Interview Guide would be taken into account during sampling, questionnaire formulation, and data collection processes for this dissertation. (See below)

Table 3.5: Household Food Insecurity Access Scale Questions

S/N	In the past 30 days,	Yes	No
2.1	Did you worry that your household would not have enough food?		
2.1a	If 'yes' how many days within the month?		
2.2	Were you or any household member not able to eat the food kinds you/s/he preferred because of a lack of resources?		
2.2a	If 'yes' how many days within the month?		
2.3	Did you or any household member have to eat a limited variety of foods due to lack of resources?		
2.3a	If 'yes' how many days within the month?		
2.4	Did you or any household member have to eat some foods that you/s/he did not want to eat because of lack of resources to obtain other types of food?		
2.4a	If 'yes' how many days within the month?		
2.5	Did you or any household member have to eat a smaller meal because there was not enough food?		
2.5a	If 'yes' how many days within the month?		
2.6	Did you or any household member have to eat fewer meals/day because there was no food?		
2.6a	If 'yes' how many days within the month?		
2.7	Was there ever no food to eat in your household because of lack of resources to get food?		
2.7a	If 'yes' how many days within the month?		
2.8	Did you or any household member go to sleep at night hungry because there was not enough food?		
2.8a	If 'yes' how many days within the month?		
2.9	Did you or any household member go without eating anything a whole day and night?		
2.9a	If 'yes' how many days within the month?		

Source: Coates, Swindale and Bilinsky (2007)

e) Analysis of qualitative data

The qualitative data (that is obtained through key informant interview, and observation) was analyzed through interpretative analysis focusing on providing meanings and explanations to the perceptions of the informants so as to dig out issues under investigation. This is used to identify climate-smart agricultural practices and innovations in agricultural production systems as well as to assess observed effect of climate change on crop production and farmers' adaptation responses in the area. This technique is also be used to investigate climate related hazards/extremes experienced by the farmers in view of its implication to food security and livelihoods. Moreover, perception of the respondents as regard to the major causes that induce climate change in the area and its implications to agricultural productivity, livelihoods systems, technology selection and adoption was addressed through interpreting the qualitative means.

3.3. Validity and reliability of tools and techniques

Reliability and validity reveal two strands in mixed research approach: firstly, with regards to reliability, whether the result is replicable. Secondly, with regards to validity, whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure (Creswell and Miller, 2000). Engaging multiple methods lead to more valid, reliable and diverse construction of realities. This is achieved by what Creswell and Miller (2000) say triangulation. In this definition triangulation is 'a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study'. This implies that the involvement of triangulation of several data sources and their interpretations with those multiple perceptions eliminate bias and increase the researcher's truthfulness of a proposition about some social phenomenon. The researcher took the two standards in to account in the course of undertaking the research. The researcher gave the tools for content validity review were reviewed by the advisor of the thesis.Based on the comments from him, some amendments were made. The reliability of the data collection is ascertained because items were set based exhaustive review of literature. Besides that, the reliability of the items in the questioner was assessed using *Cronbach's alpha test*. *Cronbach's alpha test* computed to assess the internal consistency reliability of the questionnaire items as a whole was 0.72. It shows an acceptable level of internal consistency among the items. Nunnally and Bernstein (1994) describe that *Cronbach's alpha test* value of 0.70 or higher meet the accepted standard of internal consistency reliability.

CHAPTER IV: RESULTS AND DISCUSSIONS

4.1. Demographic and socioeconomic characteristics of sample respondents

4.1.1. Demographic profile of the respondents

This section presents the demographic characteristics of the respondents so as to give a brief account on this variable as one of the key aspects of the respondents. These variables help to clearly depict the demographic features of the respondents to support the analysis on the issues under investigation such as food security status, perception of the individual respondents on climate variability and practices related to climate smart agriculture. As indicated in UNFPA (2016), the demographic characteristics are defined in terms of sex, age, family size and marital status of household heads.

Table 4.1: Demographic characteristics of the respondents

Sex	Number of respondents	%
Female	49	24.5
Male	151	75.5
Marital status	**Number of respondents**	**%**
Single	7	3.5
Married	189	94.5
Divorced	1	0.5
Widowed	2	1.0
Polygamous	1	0.5
Age category	**Number of respondents**	**%**
20-65	186	93.0
>65	14	7.0
Education level	**Number of respondents**	**%**
Unable to read and write	121	60.5
Read and write	44	22
Formal education	35	17.5

Source: Computed based on own survey data of May 2018

The targeted households for this study were composed of both male and female headed households. As shown in Table 4.1, the majority 151 (75.5%) of the total respondents were male-headed; whereas the remaining 49 (24.5 %) were female-headed households. In fact, according to the data obtained from the H/Abote *woreda* Agricultural Office, the male-headed households account for 80.4% and the female headed households account for 19.6% in the *woreda* in general indicating that there is very slight variation between the sex composition of this specific research and the secondary data from the office. This finding corroborates with the study of Hiwot (2018) who found 85% of the respondents were male headed and 15% were female-headed households in Girar Jarso *woreda*, nearby H/Abote *Woreda*. A recent study in Gulumakada *Woreda (*Tiblets, 2018) doesn't go with this specific finding in that 46.6% were male-headed and 53.4 % were female-headed households, may be because Tiblets' study focused on urban areas.

The marital status of the household head is presented in Table 4.1. Most (94.5%) of the household heads are married in the *woreda*. Only, 3.5% of the respondents are single; and 1% is found to be polygamous. In fact, according to the data obtained from the *Woreda* Administration Office, most of the registered households are married in the *woreda*. This finding corroborates with the study of Abate (2018) and Yien (2018) that 90.1 % of the households in Gimbichu *Woreda* and 80.1% of the households in Gambella region, Southwest Ethiopia were found to be married. This is may be because of rural areas such as H/Abote *Woreda* peoples marry at their early ages, in fact not less than 18 years in most cases.

The age group of the respondents (Table 4.1.) is taken into the analysis mainly because age is one of the important demographic characteristics of the household head in making decision to use CSA practices. In age categorization, it has taken into account that the minimum age of the respondent out of the contacted 200 total respondents, *i.e.* 20 years. On the other hand, the maximum age that an individual farmer is considered to be economically active in the area, according to the interview held with individual framers and experts in *woreda* sector offices, is 65 years. During the survey, 93% of the household head are found to be at productive age and the remaining 7% of the household head is above 65 years. This shows that most of the respondent household heads fall in the category of active workforce or productive age; that is 20 to 65 years. The farmers in this group are found to be experienced in the crop production and they are capable of adopting CSA agricultural technologies to their farms. This group has a better capacity to maximize CSA practices to realize their livelihoods and food security status. The interview data with experts in *woreda* Agricultural Office indicates that farmers in this age group are very productive and they are able to work hard in their field to produce more outputs. This finding corroborates with the study of (Getaneh, 2017) who found 63% of the households in East Gojam Zone were found to be productive age.

In this study, the education level of the respondents is classified into three *i.e* (1) not read and write, (2) read and write, and (3) formal education categories. Accordingly, the study found that the household heads who are '*unable to read and write'* is relatively higher *i.e* 60.5% of the total accessed households. Next to this category, the respondents who could read and write in the study *woreda* were found to be the second highest category *i.e* 22%. The third one is formal education (from grade one up to four only) in which about 17.5% of the respondents are found. In fact, according to the data obtained from the *woreda* administration office, most of the rural people in the *woreda* are unable to read and write. This is a bit different from the study of Zeritu (2018) in which 61.41% of the households in Sebeta peri-urban areas were unable to read and write. Solomon (2005) also found 50% of the total household unable to read and write in the study he carried out in most parts of upper Blue Nile Basin. This difference may be because rural areas, such as H/Abote, have less education opportunity and facility as compared to urban areas such as Sebeta.

About 99.5% of the inhabitants in the *woreda* are followers of Ethiopian Orthodox Christianity and very few of them are followers of Islam. The key informants for this research were unable to put the correct figure. Concerning language and ethnicity, in H/Abote, majority of the people speaks *Afan* Oromo and they are Oromos as well. In addition to this, there are also few immigrants speaking Amharic language. This finding corroborates with the study of Birhan (2018) that 52.6% of the households in Bole sub city Addis Ababa were found to be followers of Ethiopian Orthodox Christianity. Though it doesn't go with the findings of Getaneh (2017) of the households in Wojel *Woreda* where 63% were Muslims and the remaining 37% were Orthodox Christians. According to the information from the key informants, being an Orthodox Christian or a Muslim has a key importance in agricultural practices in that the Christians remain free from their daily farming duties observing Saint days such as the 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 12^{th}, 19^{th}, 21^{st}, 23^{rd}, 24^{th}, 27^{th}, and 29^{th} days of a month.

4.1.2. Major economic activities in H/Abote *Woreda*

Regarding economic activities, people in the *woreda* are engaged in different economic activities. To precisely indicate agriculture, firewood sale, petty trade, daily labor, land rental and oxen rental are the major livelihoods in H/Abote *woreda*. The farming economic activity of the households is mixed farming system: crop production and livestock rearing. As per key informants and observation during fieldwork, there is no modern manufacturing industry in the rural parts of the *woreda*. The only major non-farm income opportunity for the youth is an excavation site in Gidabo Jemma *Kebele* where East Cement (a Chinese owned company located in neighboring Degem *Woreda*) excavates raw material for cement manufacturing. In fact, some small-scale privately owned industries like flourmills and woodwork (carpentry) are available in Ejere town, the administrative center of H/Abote *Woreda*.

In the study area, farmers have been engaged in the agricultural activities of crop production, livestock rearing and non-farm activities. Crop production is the main source of livelihoods. Majority of the respondents have farming as the major occupation for their livelihoods. The result indicated that 38% of the respondents use only crop production activity and 53.5% of the respondents use mixed farming system (both crop and livestock).

Table 4.2: The respondents by major farming activities

Farming activities	Number of respondents	%
Crop production only	77	38.5
Livestock rearing only	12	6.0
Mixed farming	107	53.5
Off-farm only	4	2.0
Total	**200**	**100.0**

Source: Computed based on own survey data of May 2018

Only limited households in the *woreda* (only 2%) were engaging in off-farming activities like charcoal and wood sale for survival. Totally, 100% of the farmers derived their livelihoods from farming activities. In fact, according to the data obtained from the *woreda* agricultural office, about half of the respondent activity is crop production and the second is mixed farming system and the third one is livestock rearing. This finding corroborates with the study of Demisse (2018) that 40.9% of the households in Woliso *Woreda* (in Oromia Region) found to be earning their income from agriculture produce crop production.

As per the key informants, the *woreda* is a PSNP (Productive Safety Net Program) free *woreda* except the food aid schemes in case of emergency during crop damages owing to flooding (excessive rainfall), drought (shortage of rainfall). In fact, the key informants indicate that climate variability is becoming a challenge to the farmers across the *woreda*. Public services such as banking, telecommunication, schools (zero-grade to preparatory school), electric power supply and potable water service are available in H/Abote *Woreda* at present. The key informants indicated that electricity and potable water supply in the area is limited. Electric power fails frequently; there is no potable water supply for most of the time. This is highly adversely affecting other socioeconomic sectors like education, restaurants, office services, health services, urban sanitation, and stationery services.

4.2. Major CSAs practice in H\Abote *Woreda*

As discussed earlier Climate smart agriculture (CSA) was defined by FAO (2010) as agriculture that sustainably increases productivity, enhances resilience of livelihoods and ecosystems, reduces and/or removes greenhouse gases (GHGs) and enhances achievement of national food security and development goals. CSA helps ensure that climate change adaptation and mitigation are directly incorporated into agricultural development planning and investment strategies. In this study there are eight practices well addressed that are mulching, intercropping, composting, minimum tillage, agroforestry, crop rotation, water harvesting and improved seed practices. From eight practices three of them are were practiced in the *woreda*. Many of the farmers practice composting and almost all farmers practice crop rotation and minimum tillage practice in the *woreda*. Therefore there are no significant factors which makes one farmer different from the other in terms of practicing composting, minimum tillage and crop rotation practices.

4.3. Farmer's perceptions towards climate change risks in H/Abote

As per temperature and rainfall variability reported by respondents in Table 4.3, 33% of them have reported as there is no change of rainfall over years; while 67% of them have felt as there is moderate change in rainfall amounts. One of the variability aspects of rainfall reported by respondents is a delayed onset in summer season (June, July and August) and recurrent/erratic nature during spring and autumn seasons. These seasons are important agricultural periods for highland areas of Ethiopia such as H/Abote *Woreda*. Based on these facts, 23.5% of them have reported changes in early offset; while 76.5% of respondents felt no change in early offset. According to an expert during interview at the woreda agricultural office, changes in early offset are more prevalent in *qola* zone than it does in *woina dega* and *dega*.

The perception of households on variability and trends have been analyzed and presented in Table 4.3. In same manner, about 70% of the respondents indicated to have perceived drought as a climate-change induced adverse factor and half of the respondents indicated late onset of rainfall as a climate-change induced adverse factor. And 23.5% of them indicated early onset of rainfall as a climate-change induced adverse factor; while 60.5% indicated early ending of rainfall as a climate-change induced adverse factor. Heavy rainfall as a climate-change induced adverse factor was felt by 29% of the respondents; whereas high temperature as a climate-change induced adverse factor was perceived by 28% of them. Likewise, 43.5% of them indicated to have perceived very cold weather as a climate-change induced adverse factor.

Table 4.3: Perception of households on variability and trends in rainfall and temperature

Perception of households on variability and trends	**No**		**Yes**	
Variability and trends in temperature and rainfall	Count	%	Count	%
Flooding as a climate-change induced adverse factor	66	33.0	134	67.0
Drought as a climate-change induced adverse factor	61	30.5	139	69.5
Late onset of rainfall as a climate-change induced adverse factor	100	50.0	100	50.0
Early onset of rainfall as a climate-change induced adverse factor	153	76.5	47	23.5
Early ending of rainfall as a climate-change induced adverse factor	79	39.5	121	60.5
Heavy rainfall as a climate-change induced adverse factor	142	71.0	58	29.0
High temperature as a climate-change induced adverse factor	144	72.0	56	28.0
Very cold weather as a climate-change induced adverse factor	113	56.5	87	43.5

Source: Computed based on own survey data of May 2018

However, 33% of the household doesn’t perceive flooding as a climate-change induced adverse factor; whereas 30.5% isn’t worried about drought as a climate-change induced adverse factor. In the same manner, late onset of rainfall as a climate-change induced adverse factor isn’t a problem for half of the respondents while early onset of rainfall isn't a problem as a climate-change induced adverse factor for 76.5% of them. Similarly, for 39.5% of the respondents, early ending of rainfall isn't a problem as a climate-change induced adverse factor while 71% do not perceive heavy rainfall as a climate-change induced adverse factor. High temperature as a climate-change induced adverse factor isn't perceived by 72% of the respondents while 56.5% are not considering very cold weather as a climate-change induced adverse factor.

4.4. Farmers by climate change adaptation techniques

The average annual total rainfall between 1983 and 2016 is 1,196mm. The small annual total rainfall was recorded to be 950mm (in 1984) while the highest value is 1,450mm (in 1996). The coefficient of variation for over the 34 years is only 0.103 (the standard deviation being 12.47) indicating that the variation in annual total rainfall in the area is insignificant.

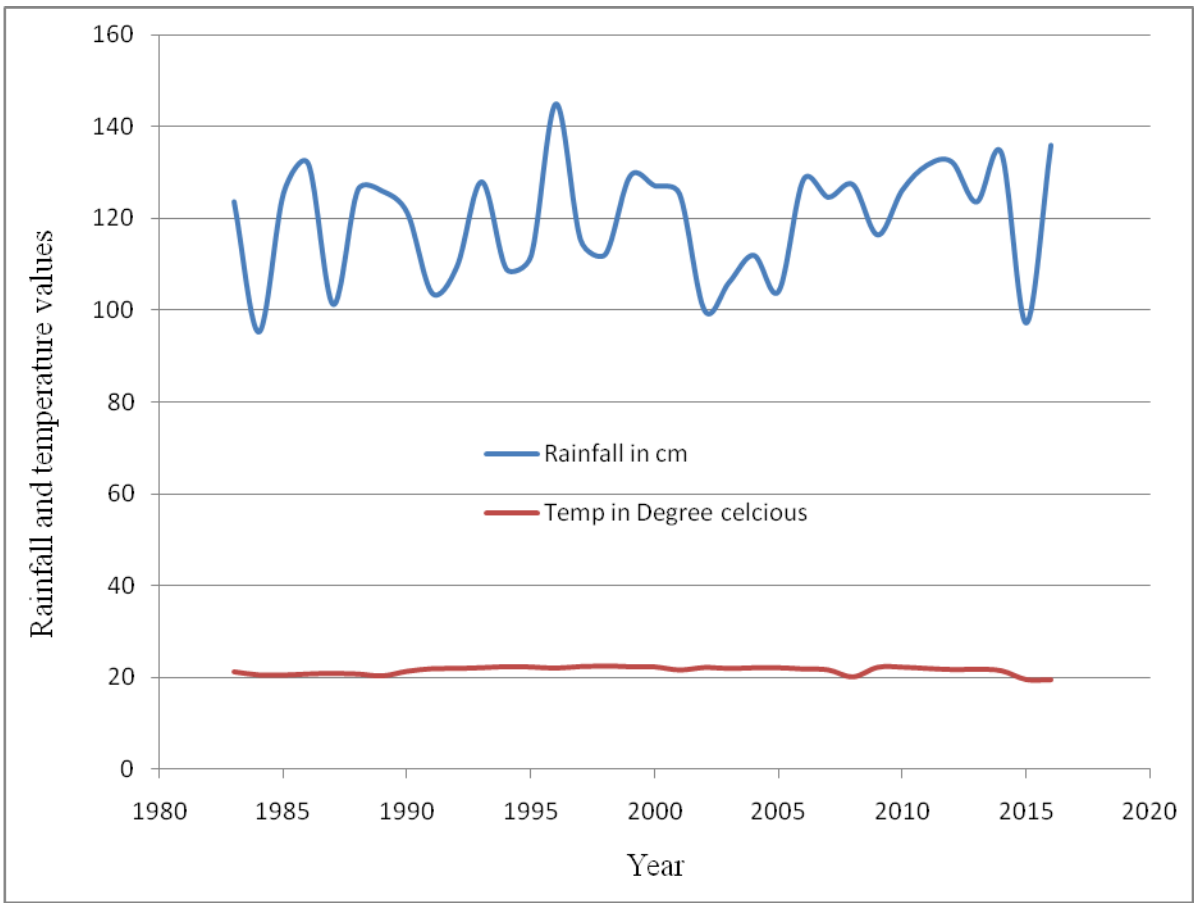
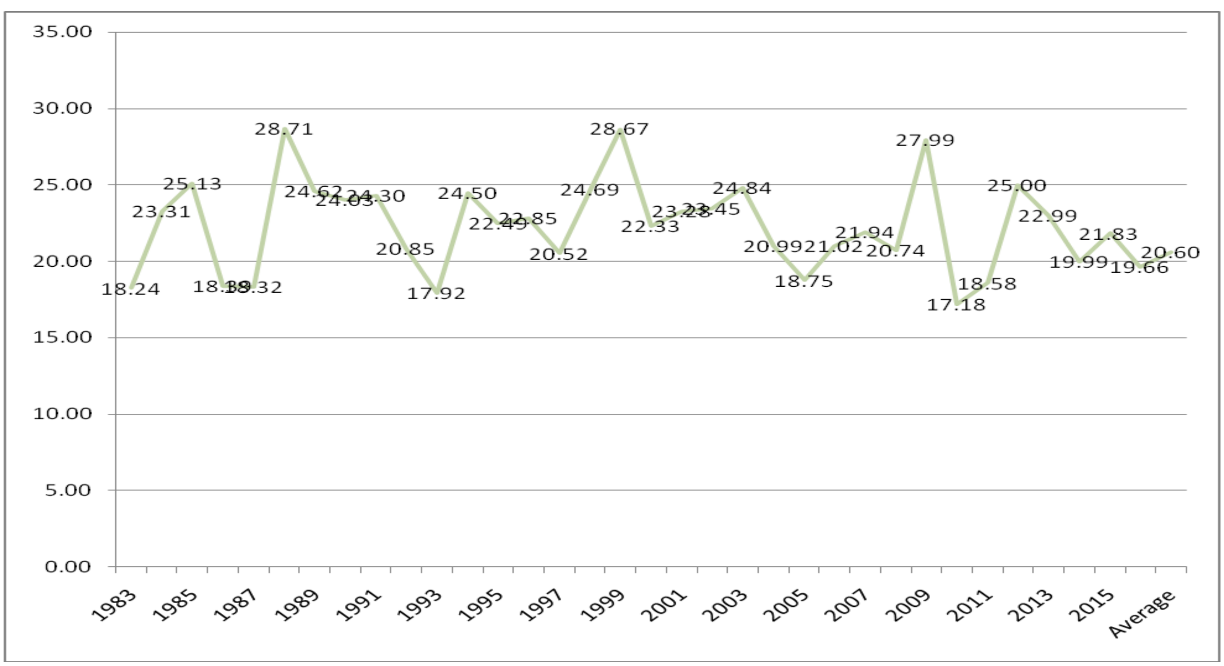


Figure 4.1: Trend of mean annual rainfall (mm) and temperature in ^{o}C (Source: Computed based on raw data obtained from NMA)

As shown in Figure 4.1 annual total rainfall in the area is slightly variable. Result of climate variability descriptors has revealed as the area is slightly experiencing decreasing rainfall and slightly increasing temperature patterns year the last three decades. The key informants disclosed that the area is characterized by high rainfall variability, high precipitation concentration (mainly July and August) and erosive rainfall, frequent drought episodes and creeping aridity manifested through erratic rainfall, frequent droughts and destructive floods have become the recent phenomena affecting their agricultural practices and livelihoods. This variability is found to menace crop and animal productivity, which is a sole livelihood for rural people while causing food production gaps and resultant food insecurity.

As shown in the Precipitation Concentration Index analysis output (Figure 4.2), the average PCI value in the area is 20 indicating the fact that rainfall in the area is highly concentrated in few months. The key informants also indicate that the rainiest months in the area are July and August. This is the time that the area receives heavy and erosive rainfall. The analysis in the figure indicates that years 1998, 1999 and 2009 are the period when the PCI hit a record of about 29 values, showing very high concentration of rainfall to a few months of the years.

Figure 4.2: Precipitation concentration index



Source: Computed based on raw data obtained from NMA)

Table 4.4: Respondents' adaptation practices to climate change

Climate change adaptation techniques	**No**		**Yes**	
	Number of respondents	%	Number of respondents	%
Cultivating varieties of crops	20	10.0	180	90.0
Changing the cropping pattern and sowing date (early/late sowing)	3	1.5	197	98.5
Cropping of drought resistance crops	188	94.0	12	6.0
Application of soil and water conservation practices	20	10.0	180	90.0
Shifting to nonfarm activities	105	52.5	95	47.5
Application of water conservation practices	171	85.5	29	14.5
Planting of trees	39	19.5	161	80.5
Application of irrigation	163	81.5	37	18.5
Using chemical fertilizers	7	3.5	193	96.5
Using organic fertilizers	4	2.0	196	98.0
Using improved seeds	153	76.5	47	23.5
Using BBM technology	200	100.0	0	0.0

Source: Computed based on the survey data, May 2018

The farmers in the area do not keep silent to the problems caused by the climatic factors. As the table above shows, they have adopted different practices to mitigate or adopt to climate changes adverse factors. Majority of the total respondents (90%) replied that they were using production of different crop varieties to cope up climate change adverse impacts. In fact, the data obtained from the *woreda* agricultural office also shows that the productions of different crop varieties is well practiced in the study area. Related study (Demise, 2018) has shown the use of producing different crop varieties as a good mechanism to cope with adverse climate change influences in Woliso (Oromia Region) Central Ethiopia. Changing the cropping pattern and sowing date (early/late sowing) was found to be one of the techniques to cope with adverse impacts of climate change and variability in the *woreda*. As shown in Table4.4, most of the respondents (98.5%) were using changing the cropping pattern and sowing date (early/late sowing) for production as a technique to cope with adverse climate change influences. Only the negligible proportion of respondents about (only 1.5%) were found to be not using changing the cropping pattern and sowing date (early/late sowing) for production to manage negative impacts of climate change influences. In fact, the data obtained from the *woreda* agricultural office shows that the productions of changing the cropping pattern and sowing date (early/late sowing) were well practiced. Related study by Demise (2018) indicated that the use of changing the cropping pattern and sowing date (early/late sowing) is a good mechanism to resist climate change influences in Woliso *woreda*.

In Abote *woreda* cropping of drought resistance crops is not familiar to the household farmers. As shown table 4.4, most of the respondents 188 (94%), were not using drought resistance crops. Only limited number of (6%) household's respondents were adopting drought resistant crops to cope up climate change impacts. In fact, the data obtained from the w*oreda* agricultural office shows that the productions of drought resistance crops were not practiced in the study area. As indicated in literature review section of this research, FAO (2016) indicated that drought and diseases tolerant crop varieties are adaptive crop varieties that are stress tolerance and disease resistance; early maturing to avoid crop loss from shorter growing seasons or unreliable rains. This leads to improved productivity and reduced risk of crop failure and drought tolerant & deeper rooted fodder grasses & legumes Contributes towards food security and increased livestock productivity. It was also indicated that use of improved fodders leads to reduction of emissions from enteric fermentation of livestock through improved digestion.

Presence of soil and water conservation practices are found to be one of the techniques used to cope with adverse impacts of climate change and variability in the *woreda*. As shown table 4.4, most of the respondents 180 (90%) were using soil and water conservation practices. The remaining 20 household respondents (10%) were not using soil and water conservation practices in the *woreda*. In fact, the data obtained from the *woreda* agricultural office shows that the use of soil and water conservation practices is well practiced in the study area. Related study by Nyasimi, *et al.* (2017) indicate that this practice promotes an integrated soil, water and nutrient management by retaining water and the use of crop residues to support the pits leads to improved and sustained soil fertility and crop productivity, reduced soil erosion, and enhanced soil carbon sequestration.

Some of the respondents (*i.e.* 95 of them or 47.5%) were found to be practicing to non-farm activities. As the same time, the *woreda* agricultural office showed that in the study area almost half of respondents well practiced farm activities. In the study area most of the respondents 161

(80.5%) were using planting of trees. As the same, the *woreda* agricultural office showed that in the study area, above half of household respondent well practiced planting trees. Related study Nyasimi, *et al.* (2017) indicate that Trees nursery provide income. The planted trees increase soil fertility and can help control erosion, as well as provide fuel wood and timber, medicines and fruits. Trees can also store substantial amounts of carbon. About 163 (81.5%) of the total respondent were not using irrigation practices. As the same, the *woreda* Agricultural office showed that in the study area, above half of household respondent were not practiced irrigation. As indicated in literature review, FAO (2016) indicated that small-scale irrigation offer key opportunities for adaptation as water supplies dwindle and rainfall becomes more erratic. Through irrigation, farmers can diversify into high value vegetable production thus reducing risks of crops loss and increasing incomes.

In H/Abote *Woreda* almost all household respondents were using both chemical and organic fertilizers. As shown Table 4.4 most all respondent, 193 (96.5%), were using chemical. Composting of crop residues and organic domestic wastes is used for soil fertility and improve crop productivity. Also contributes to improved soil structure, moisture retention and reduced emissions from application of raw animal manure. All the people were not practicing broad bed maker (BBM) technology and they don't have enough knowledge about BBM technology. From the total respondent most of the respondents 153 (76.5%) were not using improved seed varieties and the remaining negligible number of respondents about 47 (23.5) were found not using improved seed varieties. This result shows the household respondents have low access to cope up climate change problem. As the same, the *woreda* agricultural office is of the same opinion that the farmers in the woreda are not practicing improved seed varieties to cope up with the changing climatic factors.

4.5. Farmers awareness, and willingness to adopt CSA

The result of the survey indicated that farmers, who are implementing CSA practices, do not have good perception on the advantage of introduced climate smart agricultural measures. As shown in Table 4.6, about 63% of the respondents replied that they had no awareness on CSA while about 81% had no access to training on CSA related issues. Surprisingly, 97% o of the respondents are found to be willing to accept CSA practices as a strategy to cope up the adverse impacts of climate change. This shows that though the degree and efficiency varies from household to household, majority of the farmers know that CSA practices directly or indirectly benefit them for enhancing their productivity.

Table 4.5: Awareness, access to training and willing to practice CSA approaches

Farmers Approach on CSA	No		Yes		Total	
	Count	%	Count	%	Count	%
Awareness on CSA	126	63.0	74	37.0	200	100
Training on CSA	163	81.5	37	18.5	200	100
Willingness to accept CSA	6	3.0	194	97.0	200	100

Source: Computed based on own survey data of May 2018

The information from the *woreda* sector offices indicate that technical trainings have been given for the farmers on climate smart agricultural activities. About 18.5% of the respondents who had implemented the CSA practices have a strong believe that it is an advisable measure to achieve a better production, improve soil fertility, protect the land from degradation. The fact that about 97% of the respondents are willing to accept CSA practices is a good indication for the government and any concerned non-governmental organizations to support the farmers in the woreda through practical interventions so as to enable them to cope up with the inevitably of upcoming climate changes and its adverse impacts if things remain the same as it was.

4.6. Determinants of CSAs practice

Logistic regression technique was employed to analyze the determinants of CSA practices among the respondent in H/Abote *Woreda*. The study forwarded the following hypotheses at the outset of this analysis.

Location variables (agro-ecological zones, distance from market), demography factors (family size, sex and age), socioeconomic factors (education, annual income, land size, livestock size, family members involved in off-farm activity, and farming experience), institutional factors (access to credit, extension services, weather information), and quality of farmland (slope, fertility) are regressed over the CSA practices of the households as dependent variables.

Multicollinearity, linearity, normality, homoscedasticity (homogeneity of variance) and VIF test were conducted.

Eight dichotomous CSA variables (mulching, inter-cropping, crop-rotation, agro forestry, composting, minimum tillage, and water harvesting) were identified as dependent variables. These variables were then regressed using the aforementioned independent variables.

Table 4.6: Colinearity statistics

Parameters		Colinearity Statistics			
		Eigen value	Condition Index	Tolerance	VIF
	(Constant)	*10.195*	*1.000*		
$X_{2:}$	Age of the household head	1.035	3.139	0.169	5.904
$X_{5:}$	Total annual income per household	0.957	3.264	0.562	1.778
$X_{6:}$	Total livestock unit per household	0.767	3.647	0.438	2.283
$X_{7:}$	Number of oxen per household	0.645	3.977	0.479	2.088
$X_{8:}$	Annual crop production (quintals) per household	0.425	4.900	0.316	3.161
$X_{9:}$	Total farm size of household in hectares	0.274	6.097	0.348	2.874
$X_{12:}$	Frequency to agricultural extension agent per year	0.229	6.672	0.869	1.150
$X_{15:}$	Experience in agriculture in years	0.169	7.759	0.151	6.606
$X_{17:}$	Average distance of residence of the household from main farmland in km	0.112	9.536	0.601	1.663
$X_{18:}$	The nearest market from households' residence in km	0.077	11.511	0.605	1.653
$X_{20:}$	Utilization of fertilizers per hectare in the last cropping year in kg per hectare	0.054	13.721	0.519	1.926
$X_{21:}$	Utilization of improved seed per hectare in kilogram in the last crop year	0.030	18.409	0.886	1.129
$X_{24:}$	Number of household members engaging in off-farm activities	0.025	20.298	0.843	1.186
$X_{27:}$	Number of crops- diversity of crops	0.007	37.605	0.535	1.869

Source: Computed based on own survey data of May 2018

The table 4.7above explored some of the pair of variables especially the relationship between each of the independent variables with the dependent variable and their correlation coefficient is larger than 0.67. This shows a strong positive relationship between the variables. Many of the independent variables are significantly related to each other to the error level less than 5% but the magnitude of their relationship is less than 0.5 or gets close to 0 values. In the correlation matrix derived from independent variables, it is observed that there is some relationship among the independent variables. However, to simplify the regression model only the main effects of these independent variables and categorical variables (sex and age) were considered assuming that the interaction effect would complicate the model.

All the statistics in the table above indicates that there less problem (non-significant) multicollinearity in the independent variables. According to SPSS user manual when several *Eigen values* are close to zero the variables are highly inter-correlated and small changes in the data values may lead to large changes in the estimates of the coefficients. It also states that a condition index greater than 15 indicates a possible problem and an index greater than 30 suggest a serious problem with co linearity. With this perspective only variables (utilization of fertilizers, improved seed, members engaged in off-farm activities and diversity of crop production) are somewhat interrelated and all the rest have less problem of multicollinearity. Besides, many of the variables have condition index less than 15 indicating that the relationships among these variables is insignificant. Tolerance (1- R^2) and VIF (Variance Inflation Factor = reciprocal of tolerance) are another multicollinearity statistics which are used to determine how much the independent variables are related to one another (multicollinear). According to SPSS Manual, a variable with law tolerance (large VIF) contributes little information to a model. Most of the variables have large tolerance values which are close to 1 indicating that there is little multicollinearity among the independent variables in the model and thus they have significant contribution to the model.

Normality of the dependent and independent variables (age, income, TLU, annual production, and farm size) and the dependent variable (effective use of improved agricultural practices) was also carried out in order to determine the regression model that is fit for dependent variable against the independent variables.

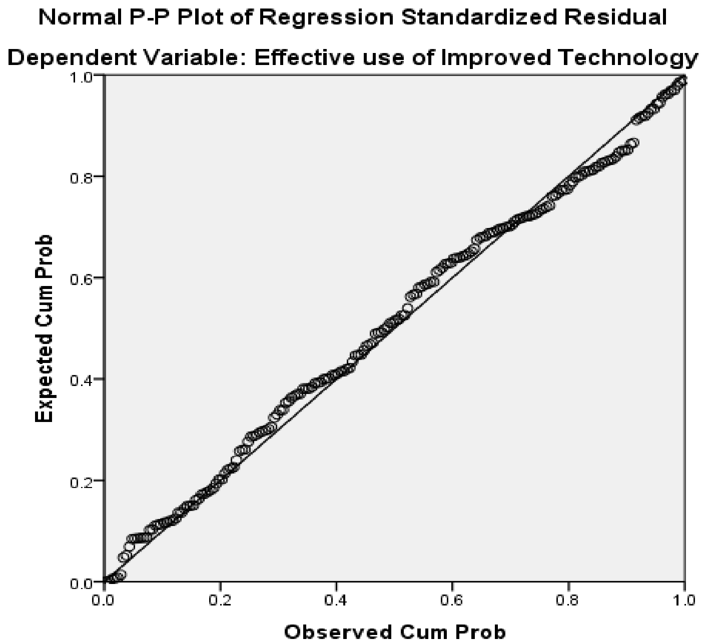


Figure 4.3: Normality test

Some of variables (annual income, livestock ownership, total production, no. of oxen, farm-size) are neutrally positively skewed and these variables were transformed to normal distribution by applying non-equal classification. To numerically test whether or not each of the variables in the model is normal or not ***Kolmogorov-Siminirov and Shapiro Wilk tests*** of normality were applied.

The normality of each of the variables was tested using the ***P-P plot*** and basic statistics of its derivatives is given in Table 4.8. The observed points are more or less aligned to the diagonal line indicating that the distribution of scores in the logistic model of customer preference against brand the independent variables is close to normal.

Table 4.7: Test of normality

Variables		*Kolmogorov-Smirnov test*			*Shapiro-Wilk test*		
		Statistic	Df	Sig.	Statistic	Df	Sig.
X_2:	Age of the household head	0.086	200	0.001	0.968	200	0.000
X_4:	Household size	0.122	200	0.000	0.973	200	0.0001
X_5:	Total annual income per household	0.160	200	0.000	0.927	200	0.000
X_6:	Total Livestock Unit per household	0.253	200	0.000	0.828	200	0.000
X_7:	Number of oxen per household	0.328	200	0.000	0.808	200	0.000
X_8:	Annual crop production (quintals) per household	0.211	200	0.000	0.898	200	0.000
X_9:	Total farm size of household in hectares	0.228	200	0.000	0.894	200	0.000
X_{12}:	Frequency to agricultural extension agent	0.323	200	0.000	0.637	200	0.000
X_{15}:	Experience in agriculture in years	0.118	200	0.000	0.964	200	0.000

X_{17}:	Average distance of residence of the household from main farmland in km	0.395	200	0.000	0.333	200	0.000
X_{18}:	The nearest market from household's residence in km	0.200	200	0.000	0.882	200	0.000
X_{19}:	Utilization of fertilizers per hectare in the last cropping year in kg per hectare	0.286	200	.000	0.812	200	0.000
X_{21}:	Utilization of improved seed per hectare in kilogram in the last crop year	0.435	200	.000	0.430	200	0.000
X_{22}:	Household participation in field days	0.348	200	.000	0.636	200	0.000
X_{24}:	Number of household members engaging in off-farm activities	0.514	200	.000	0.389	200	0.000
X_{27}:	Number of crops- diversity of crops	0.188	200	.000	0.914	200	0.000

Source: Computed based on own survey data of May 2018

In the table above significance of normality tests for both the transformed and non-transformed independent variables have become less than 0.05 indicating that the scores in all the dependent and independent variables are normally distributed.

Levene test of the homogeneity of variance is used to see the homogeneity (equality of the variances of the dependent variables) across all level combinations of the between-subjects factors, for between-subjects factors (agro-ecological zone, sex, education, slope and fertility of farmland, access to institutional services, awareness and training on CSA, etc.). This is a test of homogeneity of error variances of the regression model for effectiveness against independent variables.

Table 4.8: *Levene's test* of equality of error variances

F-factor	df1	df2	Sig.
1.758	193	6	0.245

Note: Tests the null hypothesis that the error variance of the dependent variable is equal across groups. Dependent Variable: Level of Farmer's CSA Practice (0 – no practice, 8 practice on all CSAs)

The *levene's test* of equality in Table 4.9 tells us that the error variances in the regression model (for effective use of improved farming practices against the independent categorical and numeric variables) across categories of the independent categorical variables is equal or the samples in the categorical variables have come from the same (homogenous) population. The table given above also tells that the variances of the dependent variable (effective use of improved agricultural practices) across categories of agro-ecology, sex, access to institutional services, awareness of CSA…) has become insignificant indicating that a logistic regression model can be fit for the dependent variable against independent variables containing categorical and numeric variables.

4.6.1. Results of logistic regression approach

A Logistic regression is the most common form of the regression analysis. As predictive analysis, logistic regression is used to describe data and to explain the relationship between one dependent and two or more independent variables. Therefore, in order to determine the explanatory power of the independent variables in the variance of the dependent variable, logistic regression analysis was employed. In other words, logistic regression was conducted in order to see contribution of factors to the variation in farmer's level of practicing improved agricultural techniques as adaptation techniques to the changing climate factors.

The logistic regression model was fit for the dependent variable (effectiveness of practicing improved agricultural techniques) against the location distance from market, distance from farm), demographic variables (sex, age and family size), socioeconomic factors (income, farm size, livestock size and total production) and institutional factors (access to extension services, credit services, weather information, awareness and training). The over overall model has become strongly significant with F = 3.08, Sig value = 0.001, and coefficient of determination (R^2) = 0.448. This indicates that to what level farmers adopt improved agricultural practices can be predicted using this model combining demographic factors, socioeconomic factors and institutional factors. The table below shows that agro-ecology, age, annual income, frequency of extension services, fertilizers used, improved seed used, no of crops (diversity of crop production), access to extension services, credit services and severity of climate change have been found to significantly (to the error level < 5%) influence the level of adaptation of improved farming practices (regardless of the varied magnitude of their effects).

Table 4.9: Regression model fit for effective use of improved agricultural practices

Parameters	*B*	*SE*	*T*	*Sig.*
Intercept	1.802	0.499	3.614	0.000
Agro-ecology	-0.739	0.226	-3.272	0.001
Credit access	0.303	0.120	2.527	0.012
Access to extension agents	0.333	0.135	-0.248	0.080
Severity of climate change (High)	0.475	0.222	2.141	0.034
Severity of climate change (Medium)	0.413	0.206	2.006	0.046
Age of the household head	0.457	0.012	0.610	0.054
Annual income of the household	0.414	0.032	-0.441	0.043
Frequency extension agent visit	0.653	0.003	-0.908	0.036
Fertilizers used	0.002	0.001	3.394	0.001
Improved seed used	0.003	0.001	2.621	0.010
Number of crops cultivated (diversity)	-0.133	0.063	-2.115	0.036

a. This parameter is set to zero because it is redundant.

a. R Squared = 0.448 (Adjusted R Squared = 0 .338)

***Note:** Dependent Variable: Effective use of improved agricultural practices.*

Source: Computed based on own survey data of May 2018

4.7. Factors influencing CSA practices in H/Abote Woreda

4.7.1. Determinants of mulching

The probability that farmers practice mulching depends significantly on location (agro-ecologic zone), demographic factors (sex and family size), socioeconomic factors, quality of farmland (fertility status of farmland) and institution factors. These are the factors which influence farmer’s adaptation of improved agricultural practices to the error level less than 5%. Being in the *dega*, *woina dega* or *qola*, being male or female headed household head, being illiterate or literate, having or not access to credit and having access to extension services increase the chance (probability) that farmers adopt improved agricultural practices by 9.005, 3.146, 3.221, 2.843 and 2.339 times respectively. As annual income, distance to farm and distance to market, crop production and awareness on CSA increases by one unit the chance to adopt mulching practices decreases by 0.001, 0.148,0.645,0.935 and 2.239 times respectively.

Table 4.10: Estimates of parameters of the *logisti*c model for mulching practices

Variables	***B***	***S.E.***	***Wald***	***Df***	***Sig.***	***Exp (B)***
Agro-ecology	9.005	4.542	3.931	1	0.047	8145.528
Sex of household head	3.146	1.027	9.377	1	0.002	23.242
Education level of household head	3.221	1.574	4.189	1	0.041	25.063
Annual income of the household	-0.001	0.001	3.361	1	0.067	0.999
Oxen possession	1.376	0.637	4.665	1	0.031	3.958
Crop production	-0.148	0.067	4.839	1	0.028	0.863
Credit access(	2.843	1.183	5.772	1	0.016	17.159
Access to extension	2.339	1.140	4.210	1	0.040	10.367
Distance from farmland	-0.645	0.267	5.849	1	0.016	1.906
Market-residence-distance	-0.935	0.494	3.576	1	0.059	2.547
Fertility farmland	5.335	1.892	7.951	1	0.005	207.464
Aware on CSA	-2.239	0.991	5.100	1	0.024	0.107
Number of crops (diversity)	1.091	0.538	4.115	1	0.043	2.978

Source: Computed based on own survey data of May 2018

4.7.2. Determinants of influencing inter-cropping

The probability that farmers practice inter cropping depends significantly on demographic factors (sex and age), socioeconomic factors (annual income, frequency of extension agent, environmental factor (awareness of CSA, training on CSA and severity of climate change). Whether a farmer practice intercropping depends on whether he is male or female, older or younger, rich or poor. While sex, awareness on CSA, training on CSA affects the probability that a farmer practice inter cropping to the error level ≤5%, the other factors in the table, however can significantly affect intercropping practice to the error level between >5-10%. That is the researcher is at least 95%confident that sex, awareness on CSA, training on CSA strongly influences farmers in the area to adopt intercropping on their farms. If it is not to the error level <10%(90% confidence), the other variables cannot be taken as factors that can significantly influence farmers inter cropping practice. Being male or female headed household head, taking training on CSA or not and having awareness on CSA or not increase the chance (probability) that farmers adopt intercropping on their farms by 9.8, 8.0 and 7.4 times respectively.

Table 4.11: Estimates of parameters of the logistic model for intercropping practices

Variables	*B*	*S.E.*	*Wald*	*Df*	*Sig.*	*Exp (B)*
Sex of household head	9.814	3.567	7.571	1	0.006	2.745
Age of household head	0.467	0.245	3.626	1	0.057	1.595
Annual income of the household	1.073	0.599	3.209	1	0.073	2.923
Frequency of extension agent visit	0.136	0.071	3.610	1	0.057	1.145
Severity level of climate change	6.657	3.817	3.042	1	0.081	7.77
Aware on CSA	7.478	2.991	4.692	1	0.039	6.50
Training on CSA	7.996	3.882	4.242	1	0.030	2.50

Source: Computed based on own survey data of May 2018

4.7.3. Determinants of agro-forestry practice

Farmers whether they practice agro forestry or not have been found to be significantly influenced by agro ecological where the farmer resides, by the number of oxen he/she has, by the amount of fertilizer he/she uses, severity of climate change in the agro ecology zone the farmer live and by whether he/she has taken training on CSA to the error level less than 5%. The table shows also that slope of the land owned by the farmer substantially (actually to the error level of about 5.7%) determines whether the farmer practice agro forestry or not. The farmer living in kola zone are unlikely to practice agro-forestry compared to those in *woinadega* and *dega* zones.

Table 4.12: Estimates of parameters of the *logistic* model for agro-forestry practices

Variables in the equation	*B*	*S.E.*	*Wald*	*Df*	*Sig.*	*Exp (B)*
Agro-ecology	-4.531	4.194	10.657	2	0.005	2.450
Number of oxen	2.174	0.768	8.012	1	0.005	8.793
Slope of farmland	2.831	1.490	3.612	1	0.057	16.966
Fertilizers used	-0.015	0.007	5.270	1	0.022	0.985
Severity level of climate change	4.165	1.731	5.786	1	0.016	64.372
Training on CSA	4.898	1.918	6.523	1	0.011	134.047

Source: Computed based on own survey data of May 2018

As the number of oxen owned by the farmer increases by one, the chance to practice agro forestry practice increases by 2.2 times. as slope of the farm changes from a plain through hilly landscape to steep landscape the chance of the farmers to adopt agro forestry increases by 2.8

times. As severity of the climate change increases from very low to very high level, the chance of the farmers to adopt agro forestry increase by 4.2 times. As the amount of fertilizer used increases by 1 kg the chance of the farmer to adopt agro forestry decreases by 0.02 times. Whether the farmer is given training on CSA is one another significant factor that leads to the farmer to adopt agro forestry. Actually the chance of adopting agro forestry practice by farmers who are trained on CSA increases by 4.9 times.

4.7.4. Determinants of crop rotation practice

The probability that farmers practice crop rotation, composting and minimum tillage does not depend significantly on any factors incorporated in this study vis a vis location (agro-ecologic zone), demographic factors (sex, education status of the household head), socioeconomic factors (annual income oxen possession, crop production, credit access, extension services, distance from farmland, distance to market), quality of farmland (farm size, fertility status, slope of farmland, severity of climate change) and institution factor (awareness of CSA, extension services). As discussed with farmers during field work and as it is enumerated by the questionnaires, crop rotation, composting and minimum tillage are common practices adopted by almost all farmers in the study area. That is whether the farmer is male or female, young or old, rich or poor, have access to institutional services or not and whether the quality of farm is poor or good, most of the farmers have adopted these practices (actually crop rotation, composting) or not adopted at all (minimum tillage). Because of the lack variability in the independent variables to explain the variability in the dependent variables (practicing crop rotation, composting, and minimum tillage), the resulting tables associated to these CSAs are placed in the appendix7.

4.7.5. Determinants of improved seed application

The amount of improved seed used by the farmers in the area depends significantly on sex, education, household size, annual income, farm size, access to credit and whether information, number of household members participated in off-farm and awareness about CSA. The chance of male headed households to use improved seed is better than female headed households. As education level of a household increases from illiterate to formal education, the chance of farmers to adopt improved seed increases by about 5 times. As the number of household size increases by one person the chance to adopt improved seed decreases by 0.33 unit times. Annual income is another factor that significantly determine whether a farmer purchase and apply improved seed. As his/her income increases by one birr the chance of him or her to use improved seed increases by 1.335 times. As the size of farmland possessed by a farmer increases by a hectare the chance of him/her to apply improved seed decreases by 1.5 times. Access to credit access is another factor that negatively affects farmers to adopt improved seed by about 3.6 times. Access to whether information and awareness about CSA are factors positively influence farmers to use improved seed by 2.5 and 2.7 times respectively. As the number of HH members involved in off-farm activities increases by one person, the chance to apply improved seed increases by 3.8 times.

Table 4.13: Estimates of parameters of the logistic model for improved seed application

Variables	*B*	*S.E.*	*Wald*	*Df*	*Sig.*	*Exp (B)*
Sex of household head	-6.371	2.857	4.971	1	0.026	0.002
Education level of household head	4.850	1.805	7.220	1	0.007	0.008
Household size	-0.333	0.194	2.959	1	0.085	0.717
Annual income	1.335	0.471	8.039	1	0.005	3.799
Farmland size in hectare	-1.536	0.808	3.610	1	0.057	0.215
Credit access	-3.575	1.471	5.902	1	0.015	0.028
Weather information access	2.506	1.284	3.810	1	0.051	12.262
Number of off-farm practitioners	3.822	1.235	9.579	1	0.002	45.705

Source: Computed based on own survey data of May 2018

4.7.6. Determinants of water harvesting practice

The last CSA practices considered in this study was water harvesting practices which found to be significantly (to ≤ 5% level of error) affected by the location the farmer resides, the number of oxen he has, access to credit and weather info, fertility of farmland and severity of climate change in the area. Age of the farm household head, access to extension services and distance of farmland to homestead were also found to affect water harvesting practices but to the error level less than 10%. Farmers in *Kolla* zone tend to adopt water harvesting more than those residing in *woina dega* and *dega* zones. As the age farmers and the number of oxen possessed by farmers increases by one unit, the chance of the farmer to adopt Water harvesting practice decreases by 0.13 and 1.5 respectively. The increasing Severity of Climate change, access to credit, access to extension services, distance of farmland from homestead cause the chance of adopting water harvesting practice by 4.1, 1.6, 1.3 and 0.25 times respectively. The increasing chance of access to weather info and fertility status of farmland decreases the chance of farmers to adopt water harvesting practice by 1.72 times and 3 times respectively.

Table 4.14: Estimates of parameters of the logistic model for water harvesting practices

Variables	***B***	***S.E.***	***Wald***	***Df***	***Sig.***	***Exp (B)***
Agro-ecology	8.271	3.292	6.312	1	0.012	0.000
Age of household head	-0.132	0.078	2.838	1	0.092	0.877
Number of oxen	-1.455	0.632	5.303	1	0.021	0.233
Credit access	1.643	0.828	3.939	1	0.047	5.169
Access to extension agents	1.305	0.792	2.717	1	0.099	3.688
Weather information access	-1.718	0.869	3.914	1	0.048	0.179
Distance from farmlands	0.248	0.142	3.038	1	0.081	1.281
Fertility level of farmlands	-3.060	1.315	5.412	1	0.020	0.047
Severity level of climate change	4.106	2.092	3.855	1	0.050	60.733

Source: Computed based on own survey data of May 2018

4.8. CSA and household food security: The nexus

This research finds that those households practicing CSAs are likely to produce (have high agricultural productivity or large volume of production) more than the farmers who don’t practice CSAs. The farmers with large volume of production are likely to more food secure than those who produce little which may not feed all household members all year round. In the face of today’s climate change those farmers practicing CSAs effectively have little risks of losing all harvests than those farmers who have little practice on CSAs. Our country is poor (less accessible to all farmers) and thus those farmers practice CSAs effectively are less vulnerable than those farmers who have little experience on CSAs.

As discussed with key informants, in H/Abote *Woreda* the food security status of most people is deteriorating may be because of their little experience in CSAs practices which could have improved their agricultural productivity and production. Improved agricultural productivity and earning higher production could have been a potential to feed the household all year round and improve household's income.

Table 4.15: Household Food Insecurity Access Scale HFIAS) statistics

Household food security status			Count	%	Sum
1	Whether the household worried about having no enough food in the household	*No*	48	24.0	
		Yes	152	76.0	
	Number of days within a month that the household worried of not having enough food in the household				8
2	Whether the household member worried about having not able to eat the food kinds	*No*	55	27.5	
		Yes	145	72.5	
	Number of days within a month that the household worried about having not able to eat the food kinds s/he wants				7
3	Whether the household member/s has/have eaten limited variety of foods due to lack of resource	*No*	49	24.5	
		Yes	151	75.5	
	Number of days within a month that the household member has eaten only limited variety of foods due to lack of resource				12
4	Whether the household member has eaten unwanted foods because of lack of resource to obtain other types of food	*No*	58	29.0	
		Yes	142	71.0	
	Number of days within a month that the household member has to eat unwanted foods because of lack of resource				8
5	Whether the household member has to eat smaller meal per day because of lack of enough food	*No*	55	27.5	
		Yes	145	72.5	
	Number of days within a month that the household member has to eat smaller meals per day because of lack of enough food				7
6	Whether the household member has to eat fewer meal per day because of lack of food	*No*	76	38.0	
		Yes	124	62.0	
	Number of days within a month that the household member has to eat fewer meal per day because of there was no food				6
7	Whether the household member has no food because of lack of resource to get food	*No*	127	63.5	
		Yes	73	36.5	
	Number of days within a month that the household member has no food because of lack of resources to get food				2
8	Whether the household member go to sleep at night hungry because there was no enough food	*No*	135	67.5	
		Yes	65	32.5	
	Number of days within a month that the household member go to sleep at night hungry because there was not enough food				1
9	Whether the household member go without eating anything a whole day and night because of lack of resources	*No*	151	75.5	
		yes	49	24.5	
	Number of days within a month that the household member go without eating anything a whole day and night because of lack of resources				9

Source: Computed based on own survey data of May 2018

Farmers who adopted CSAs practice are more likely to have available food production, to have an access to get enough food, and to properly utilize available food than non-adopters. As discussed with farmers during field work and as it is enumerated by the questionnaires, about 152(76%) of the total respondents were worried about having no enough food and the remaining 48(24%) were not worried about having no enough food. From the total respondent farmers have worried about having no enough food on average the farmers in the area lacks enough food at least for eight days a month. About 145 (72.5%) of the total respondents were found to be worrying about having not able to eat balanced food kinds. Only the remaining 55 (about27%) were not worrying about having not able to eat balanced food kinds. From the total respondents, were found to be worrying about having not able to eat the food kinds for seven days per month. This shows H/Abote *woreda* is one of the most food insecure areas in the country.

About 151 (75.5%) of the total respondents have eaten limited variety of foods due to lack of resource and the remaining 49(24.5%) have not eaten limited variety of foods due to lack of resource. From the total respondent farmers have eaten limited variety of foods due to lack of resource for 12 days per month. It's obvious CSAs practice adopters are food secure than non-adopters because when they use CSAs practices their productivity and income is increase and they have able to get enough, nutritious and different variety of foods than non-adopters. In H/Abote woreda about 142(71%) of the total respondents have eaten unwanted foods because of lack of resource to obtain other types of food and the remaining 58(29%) have not eaten unwanted foods because of lack of resource to obtain other types of food. From the total respondents has eaten unwanted foods because of lack of resource to obtain other types of food for 8 days per month. Most of the respondents 145(72.5%) has to eat smaller meal per day because of lack of enough food and the remaining 55(27.5%) has not to eat smaller meal per day because of lack of enough food in the woreda. From the total respondents has to eat smaller meal per day because of lack of enough food for 7 days per month. About 124(62%) of the respondents has to eat fewer meal per day because of lack of food and the remaining 76(38%) has not eat fewer meal per day and farmers has to eat fewer meal per day because of lack of food for 6days per month.

Regarding food security status of the household about 73(36.5%) has no food because of lack of resource to get food and the remaining 127(63.5%) has enough food because of efficient resource and farmers has no food because of lack of resource to get food for 2 days per month. Most of the respondents 135(67.5%) doesn't go to sleep at night hungry because there was no enough food and the remaining 65(32.5%) go to sleep at night hungry because there was no enough food and farmers go to sleep at night hungry because of lack of enough food for 1 days per month. Regarding food security status about 151(75.5%) doesn't go without eating anything a whole day and night because of lack of resources and the remaining 49(24.5%) go without eating anything a whole day and night. From the total respondent farmers go without eating anything a whole day and night for 9 days per month. Finally, this result shows that farmers in the *woreda* are more food insecure and have not access to get enough food efficiently.

4.8.1. Analysis of household food balance model

As discussed earlier in this document, the dominant food crops in the area are wheat (*Triticumaestivum*), teff (*eragostistef*), maize (*zea mays*), sorghum (*sorghum bicolor*), and barley (*hordeum vulgare*) and chick peas (*cicer arietinum*). The households were found to be producing all these food crops to meet their dietary requirements from their own production though the proportion varies among households, some producing more teff, while others may produce more wheat or barley or sorghum. This seems to be the case for most smallholders in Ethiopia.

Table 4.16: Average caloric composition of major food items consumed in the area

Major food crops in the area	**Type of food outputs**	**Average Food energy in kcal/100g**
Teff *(Eragostis tef)*	*Enjera* (large traditional pan cake) and porridge	145.0
Wheat *(Triticum aestivum)*	*Qolo* (roasted wheat seed), bread, Nifro (boiled wheat seed)	242.6
Maize (zea mays)	*Nifro* (boiled maize seed), bread (cooked maize flour with meager salt and water), *qinche* (boiled maize with salt)	393.5
Sorghum (*Sorghum bicolor)*	*Enjera* mixing with teff	168.1
Barley *(Hordeum vulgare)*	*Qolo* (roasted barley seed) and porridge	245.3
Pulses	Wet (traditional Ethiopian sauce),*Nifro* (boiled pulse seeds), and *qolo* (roasted pulse seeds)	163.5

Source: Computed based on EHNRI (1997) Food composition table and field data

In fact, some households reported to have been supplementing their domestic food requirement through purchasing from markets, emergency food aid and gifts/remittance. In Abote *woreda* farmers consume mostly wheat as injera and *qita*; maize as bread, *nifro* (boiled seed) and *tela* (traditional beer); teff as injera, *qita* and porridge; sorghum (mixing with teff) as injera; and barley as porridge, *beso (*roasted and powdered*)* and *tela*. The farmers do not consume oilseed (such as *nug* and sunflower) at home; rather they sell it for cash. The farmers in the area also produce and consume pulses such as peas, fava bean and chick peas. These crops are mostly used to prepare *wet* (Ethiopian sauce) and also consumed as *qolo* (roasted seed) and *nifro* (boiled seed). The table hereunder showing the average caloric composition of the major food items consumed in the area is established based on these descriptions

Calorie per capital analysis is one of the most complex tasks in food security study. This is because it requires a data set depicting the type and amount of individual's daily food intake which is to be the converted in to calorie equivalent. The difficulty here lies with the collection of appropriate data and the unavailability of calorie equivalent for some type or form of food items in the community. There is also a variation in the calorie equivalent of the form of food, say weather it is prepared in the form of bread, injera, *qolo* (roasted wheat seed) or *nifro* (boiled wheat seed. The calculated calorie compared against the nationally set average daily caloric requirement for a moderately active adult (2100kcal/day/person) to determine the consumption component of the food security status of the respondent's community in H/Abote. The net amount of food available was calculated by using household food balance model indicated earlier in methodology section. The net available was converted into dietary calorie equivalent using EHNRI (1997) food composition table. To this effect, the average calorie equivalent of each type of food group was computed based on the kind of food that the community consumes utmost.

As clearly indicated in FAO (2008), the analysis of food security status requires an investigation of core food security components such as physical availability of food, economic and physical access to food, utilization, and stability (sustainability) of these components. One of these techniques is analysis of dietary energy obtained from each food type or crop after cooking. The Ethiopian Health and Nutrition Research Institute (EHNRI) investigated the food energy content of each food types in Ethiopia and published a Food Composition Table. According to the EHNRI, the minimum daily food energy requirement for an adult person is 2,100kcal. This threshold is country specific and is measured in terms of the number of kilocalories required to conduct light activities. An individual whose daily dietary calorie consumption is less than this threshold is said to be under nourished and suffering from transitory food insecurity. Therefore, the Average dietary energy analysis has been carried out based on these facts.

This is because the calorie equivalent of the food items varies by the types of the end product prepared for consumption. For instance, a 100 gram of Teff *(Eragostis tef)* grain (white) prepared in the form of *enjera* or porridge produces a dietary energy equivalent to145 kilocalorie. White teff is common and stable food in the area. Wheat *(Triticum aestivum)* is another stable food in H/Abote area. On average, a 100 gram of wheat produces a dietary energy equivalent of 242.63 kilocalorie when prepared in the form of bread, *injera, kolo and nifro.* In same way, maize *(zea mays*) is widely produced a consumed in the area. On average, a 100 gram of maize is equivalent to a dietary energy equivalent of 393.5 kilocalorie if prepared in the form of bread and *Nifro* (boiled seed). By the same token, sorghum (white) is widely is used among the farmers. According to the EHNRI (1997) food composition table, a dietary energy equivalent of a 100 gram of sorghum if prepared in the form of injera (mixed with teff) is 168.1 kilocalorie. Barley *(Hordeum vulgare*) is produced and consumed in the form of porridge and *kolo* producing an average dietary energy equivalent of 245.25 kilocalorie if prepared and consumed in the form of porridge and *kolo*. Pulses like pea, fava bean and chick pea are common food crops in the area. Pulses are mostly prepared and consumed in the form of *wet* (traditional Ethiopian souse), *nifro* (boiled seed), and *qolo* (roasted seed) . The average dietary energy equivalent of pulses in these forms is 163.52 kilocalorie.

As discussed earlier in this document, the dominant food crops in the area are wheat (*Triticum aestivum*), teff (*eragostis tef*), maize (*zea mays*), sorghum (sorghum bi color), barley (*hordeum vulgare*) and chick peas (*cicer arietinum*). As shown in Appendix 12, in addition to production, the households reported to have been supplementing their domestic food requirement through remittance, emergency food aid, and purchase.

In Abote *woreda*, the farmers use wheat as *injera* and *qita*,; maize as bread, *nifro* and *tela*; teff as *injera*, q*ita* and porridge; sorghum as *injera* with mixing teff; barley as porridge, beso and *tela*, oilseed (such as nug and sunflower) for *qolo* and *fitfit*; pulses like peas, *fava bean*, and chick peas are farmers used to wet and *qolo*.

The total amount of wheat obtained through production, remittance, and food aid was about 1,692 quintals for the all sample respondent with the 2017/18 crop year. The households didn't consume all the available wheat during the year; they rather sold, reserved for seed and lost about after harvest about 824 quintals of the available wheat amount. The balance was, therefore, about 868 quintals. The balance, when converted to dietary energy, is about 2,882kcall/household/year or about 404kcal/head/year.

Similar to the case for wheat in the above paragraph, the computation was carried out for the remaining other major food crops in the area, such as barley, maize, sorghum, teff and pulses. On the average the available food energy per household was computed to be 8,760 kcal per year which is only 1,226 kcal per person per year. This value is extremely less than the nationally set food energy requirement by Ethiopian Public Health Institute i.e. 2100kcal/day/person. This tells us that the area is extremely food insecure in view of consumption and availability component Household Food Balance Model.

In Abote *woreda*, the farmers use wheat as *injera* and *qita*,; maize as bread, *nifro* and *tela*; teff as *injera*, q*ita* and porridge; sorghum as *injera* with mixing teff; barley as porridge, beso and *tela*, oilseed (such as nug and sunflower) for *qolo* and *fitfit*; pulses like peas, *fava bean*, and chick peas are farmers used to wet and *qolo*.

The total amount of wheat obtained through production, remittance, and food aid was about 1,692 quintals for the all sample respondent with the 2017/18 crop year. The households didn't consume all the available wheat during the year; they rather sold, reserved for seed and lost about after harvest about 824 quintals of the available wheat amount. The balance was, therefore, about 868 quintals. The balance, when converted to dietary energy, is about 2,882kcall/household/year or about 404kcal/head/year.

Similar to the case for wheat in the above paragraph, the computation was carried out for the remaining other major food crops in the area, such as barley, maize, sorghum, teff and pulses. On the average the available food energy per household was computed to be 8,760 kcal per year which is only 1,226 kcal per person per year. This vale is extremely less than the nationally set food energy requirement by Ethiopian Public Health Institute *i.e*. 2100kcal/day/person. This tells us that the area is extremely food insecure in view of consumption and availability component Household Food Balance Model.

CHAPTER V: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Hidhabu Abote woreda is one of the 14 *woredas* of North Shewa Zone, Oromia National Regional State (ONRS). According to the data obtained from the *woreda* administration office, there are 19 rural *kebeles* and one urban center (Ejere town) in the *woreda*. This research employed retrospective-cross-sectional study design as it would take in to account long-term climatic and the one-time socioeconomic data.

The overriding objective of this thesis was to assess how farmers cope with climate-related agriculture production shocks using local and nationally identified agricultural adaptation practices and technologies to ensure household food security in responses to climate extreme impacts on agricultural production in Hidhabu Abote district. More specifically, the study aspired to identify climate-smart agricultural practices, mitigate climate related predicaments in agricultural production in Hidhabu Abote *woreda*, explore the trends and patterns of rainfall and temperature changes in the area, look into major environmentally unfriendly agricultural practices that induce climate change in the district ,investigate climate related hazards/extremes affecting the production and productivity of the farmers in the study district ,explore innovations in agricultural practices which the farmers are adopting in Hidhabu Abote *woreda*, assess observed effect of rainfall variability on crop production and farmers' adaptation responses.

Some of the CSA concepts discussed are: zero tillage, crop rotation, composting, intercropping, water harvesting, crop residue management or mulching, crop diversification (horticulture, mushroom cultivation, etc.), agro-forestry, improved seed and water management (drip irrigation). Those practices have positive impacts on food security, improved agricultural productivity and earning higher production could be potentials to feed the household all year round and improve household's income. Farmers who adopt CSAs practice are more likely to have available food production, to have an access to get enough food, and to properly utilize available food than non-adopters. It's obvious CSAs practice adopters are food secure than non-adopters because when they use CSAs practices their productivity and income is increase and they have able to get enough, nutritious and different variety of foods than non-adopters.

Institutions must be creating and transfer useful information and guide people to interpret the new technologies into understanding and work on it.

5.2. Recommendations

The following policy recommendations have been suggested for critical consideration in light of the discussions drawn hereinbefore and the findings concluded above. The recommendations are deemed to be useful for future policy intervention regarding CSA and further investigations in planning, executing and monitoring of CSA practices so that it could be one of the key development strategies in the country. Though the recommendations derived from this paper typically target farmers in H/Abote *Woreda*, one can apply them to country level issues and envisage future possibilities regarding the role of CSA practices in mitigating environmental and socioeconomic problems of the people living in rural areas in the country.

- ✓ The findings of the research indicate that rainfall has been concentrated in a few months of a year (mainly July and August) with significant variation among years between 1983 and d2016. Therefore, concerned non-governmental and governmental organizations (such as *Woreda* Office of Agriculture and Rural Development) should work to enhance the vegetation coverage of the area so as to improve the climatic situation of the area;

- ✓ Both the HFBM and HFIAS models show that the farmers are highly facing food insecurity situation and/or severe shortage of food. Hence, the integration of sustainable agriculture, rural development and ecosystems in the context of climate change and food security is found to be vital in the study area. For this reason, concerned sector offices are recommended to work hard to boost up agricultural production to ensure sustainable food security to solve the existing food shortfalls. Improvements in environmentally friendly agricultural technologies lead to increases in food production, availability of cheaper and safer foods, and contentment in people and the government. Hence, the government should made intensive efforts to enhance agricultural technologies in order to significantly improve the precarious livelihood of the people. This can be achieved by boosting up agricultural outputs through agricultural intensification, development of irrigation schemes, effective implementation of organic fertilizers and effective environmental protection endeavors. The function of farmers training centers (FTC) is so crucial in this regard.

- ✓ Income status of the household, asset position, farmland size, access to agricultural extension agent, experience in agriculture practices, distance from farmland and market areas, use of fertilizer, application of improved seed, number of household members engaging in off-farm activities, and crop- diversity are found to be important variables in determining CSA practices. Hence, concerned sector offices and NGOs at woreda, regional and federal level are recommended to enhance these variables in the *woreda*;

- ✓ Financial asset is also found to be critical problem among the farmers. Since poor farmers have no resources to access credit and markets, and they are unable to adapt to these new techniques for the success of CSA the strong institutions have to maintain agricultural markets and financing mechanisms which are very important;

- ✓ The study shows that CSA practitioner/adopters are more food secure than the non-adopters indicating the good relationship between the two. Due to this reason, concerned sectors offices in the woreda are recommended to enhance the CSA practices through awareness creation works;

- ✓ One of the crucial problems in the area is the incapability to meet the expenses of major farm inputs such as selected seeds and agrochemicals for their agricultural activities. Particularly, they encounter difficulty in finding money for the inputs. This has slowed down the drive to attain food security in the area. Hence, it is highly recommended that the government should significantly subsidize such agricultural essentials until the farmers can afford to pay for the inputs themselves.

Reference

1. Abate_(2018). Farmers technical efficiencies in the of improved Hidase wheat variety in maximizing livelihood and food security in central Ethiopia, Gimbichui district.
2. Abduselam Abdulahi Mohamed (2017). Food Security Situation in Ethiopia: A Review Study. International Journal of Health Economics and Policy, Vol. 2, No. 3, 2017, pp. 86-96.
3. African Union /AU/ (Undated). Policy Brief: Opportunities and Challenges for Climate-Smart Agriculture in Africa, Addis Ababa
4. Agrawal, B. (2006). Basic Statistics. New Age International Publishers: New Delhi
5. Anderson, M. G. (2005). The Impact of Climate Change and Variability on Heavy Precipitation, Floods, and Droughts National Center for Atmospheric Research, John Wiley & Sons, Ltd, USA
6. Asefach, H. and Nigatu, R. (2007). Correlates of Household Food Security in Densely Populated Areas of Southern Ethiopia: Does the Household Structure Matter? Stud. Home Comm. Sci., 1(2): 85-91 (2007)
7. Bewket W, Radeny M, and Mungai C. (2015). Agricultural Adaptation and Institutional Responses to Climate Change Vulnerability in Ethiopia. CCAFS Working Paper no. 106. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org
8. Birhan (2018). Prevalence of Over Weight and Associated Factors among Private First Cycle Primary School children in Bole sub city, Addis Ababa, Ethiopia.
9. Boto, Isolina, Ronalee Biasca and Filippo (2012). Climate Change, Agriculture and Food
10. Brevik, Eric C. (2013). The Potential Impact of Climate Change on Soil Properties and
11. Bruce (2014). Reducing risks to food security from climate change. June Global Food Security DOI: 10.1016/j.gfs.2016.06.002
12. Campbell, Bruce M,Philip Thornton,Robert Zougmore, Piet van Asten and Leslie Lipper (2014). Sustainable intensification: What is Its Role in Climate Smart Agriculture? In Current Opinion in Environ teal Sustainability, ELSEVIER
13. Central Statistical Agency. (2013). Population Projection of Ethiopia for All Regions at Wereda Level from 2014-2017. Addis Ababa

14. Ching, Lim Li (2010). Climate-Change Implications for Agriculture in Sub-Saharan Africa, Food and Agricultural Organization of the United Nations, Rome
15. Christensen (2007). Evaluating the performance and utility of regional climate models: the PRUDENCE project. Climate Change, doi:10.1007/s10584-006-9211-6
16. Degefa Tolossa (1996). Belg Crop Production as a Strategy of Households' Food Security: A Comparative Study of Belg Grower and Non Belg Grower Farmers in Munessa woreda, Arssi Region. M.A Thesis. Addis Ababa University, Addis Ababa
17. Demissie (2018). Smallholder Farmers Adoption of Climate Smart Cattle Production Practices: Status and Determinants in Waliso *woreda*, Southwest *Shoa* Zone, Oromia National Regional State, Ethiopia. Demographic Characteristics of the Somali People, Somalia Country Office
18. Devereux, S. (2000). Food insecurity in Ethiopia: A discussion paper for DFID. IDS, Sussex.
19. Di Falco S., Veronesi M., and Mahmud Y. (2011). Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. American Journal of Agricultural Economics 1–18
20. Dinar, A., Hassan, R., Mendelsohn, R., & Benhin, J. (Eds.). (2008). Climate change and agriculture in Africa: Impact assessment and adaptation strategies. London: Earth Scan
21. Ethiopian Health and Nutrition Research Institute (1998). Food Composition Table for Use in Ethiopia. Part III. 1995–1997. Addis Ababa: EHNRI/FAO.
22. FAO (1996). Food production and environmental impact. Rome Italy.
23. FAO (2003). Crop breeding: The Green Revolution and the preceding millennia
24. FAO (2010). Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Paper prepared for Hague Conference on Agriculture, Food Security and Climate Change.
25. FAO (2012). Developing a Climate-smart Agriculture Strategy at the Country Level: Lessons from Recent Experience: Background Paper for the Second Global Conference on Agriculture, Food Security and Climate Change, Hanoi, Vietnam, 3-7 September 2012
26. FAO (2012). The State of Food Insecurity in the World 2012, UN Food and Agriculture Organization, Rome

27. FAO (2013). Climate-Smart Agriculture, Food and Agricultural Organization of the United Nations, Rome
28. FAO (2016). Ethiopia Climate-Smart Agriculture Scoping Study, by Jirata, M., Grey, S. and Kilawe, E. Addis Ababa, Ethiopia
29. FAO (UN Food and Agriculture Organization) (1996). Final report of the 1996 World Food Summit. Rome: FAO.
30. Fofchamps and minten and Isham (2002). Social capital and economic development: well-being in developing countries
31. Getaneh Mossu, (2017), Households Poverty and Livelihoods Nexus in Small Towns of East Gojjam, Amhara Region, Ethiopia, Doctoral Dissertation Submitted to the Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa, Ethiopia.
32. Gregory J. Retallack(2001).Cenozoic Expansion of Grasslands and Climatic Cooling The Journal of Geology Vol. 109, No. 4 (July 2001), pp. 407-426.
33. Hailemariam Teklewold, Alemu Mekonnen, Gunnar Kohlin(2018). Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia. DOI:10.1080/17565529.2018.1442801.
34. Hellin, J., Shiferaw, B., Cairns, J. E., Reynolds, M., Ortiz-Monasterio, I., Bänziger, M., et al. (2012). Climate change and food security in the developing world: potential of maize and wheat research to expand options for adaptation and mitigation. Journal of Development and Agricultural Economics, 4, 311–321.
35. Hiwet (2018). Impacts of Adopting Improved Wheat Varieties on Food Security in Girar jarso *woreda*, North Shewa Zone, Oromia Region, Ethiopia
36. Hurni, Hans (2000). Agro-ecological Belts of Ethiopia: Explanatory Notes on Three Maps at a Scale of 1:1,000,000, Research Report. Centre for Development and Environment University of Bern (Switzerland) in association with The Ministry of Agriculture, Ethiopia
37. IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva

38. IPCC (2014). Climate Change: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/report/ar5/wg3/
39. IPCC. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
40. Israel, G. D. (2012). Determining Sample Size, University of Florida, IFAS Extension.
41. Jemma Gornall, Richard Betts, Eleanor Burke, Robin Clark, Joanne Camp, Kate Willett, Andrew Wiltshire Philos Trans R Soc Lond B Biol(2010) Implications of climate change for agricultural productivity in the early twenty-first century Sci. 2010 Sep 27; 365(1554): 2973–2989. doi: 10.1098/rstb.0158
42. Koneswaran G1, Nierenberg D(2008). Global farm animal production and global warming: impacting and mitigating climate change. May; 116(5):578-82. doi: 10.1289/ehp.11034.
43. Kurukulasuria and mendelson (2009). Economic Impact of Climate Change on Crop Production in Ethiopia: Evidence from Cross-Section Measures. Journal of African Economies 18(4):529-554. DOI: 10.1093/jae/ejp002
44. Landry (2016). Plankton dynamics and biogeochemical fluxes in the Costa Rica Dome: introduction to the CRD Flux and Zinc Experiments. J. Plank. Res., 38, 167–182.
45. Lasco (2014). Agroforestry systems: Helping smallholders adapt to climate risks while mitigating climate change. DOI: 10.1002/wcc.301
46. Leslie (2014). Climate Smart Agriculture for Food Security. November 2014Nature Climate Change 4:1068–1072
47. Lipper, Leslie, Philip Thornton, Bruce M. Campbell, Tobias Baedeker, AdemolaBraimoh, MartinBwalya, Patrick Caron, Andrea Cattaneo, Dennis Garrity, Kevin Henry, Ryan Hottle,20 Louise Jackson, Andrew Jarvis, Fred Kossam, Wendy Mann, Nancy McCarthy, Alexandre Meybeck, Henry Neufeldt, Tom Remington, Pham Thi Sen, Reuben Sessa, Reynolds Shula, Austin Tibu& Emmanuel F. Torquebiau (2014). Climate-Smart Agriculture for Food Security. Nature Clim. Change 4, 1068–1072 (2014)

48. Lobel (2008). prioritizing climate change adaptation needs for food security in 2030.science 319;607-610.

49. Mahlet Teferi (2013). The Impact of Rainfall Variability on Crop Production in Kuyu Woreda, Central Ethiopia. MA Thesis, AAU.

50. Mallick, Seeme and Naghmana Ghani (2005). A Review of the Relationship between Poverty, Population Growth and Environment. The Pakistan Development Review, Volume 44, No. 4 Part II, pp. 597–614

51. Manyeruke, Charity, Shakespear Hamauswa and Lawrence Mhandara (2013). The Effects of Climate Change and Variability on Food Security in Zimbabwe: A Socioeconomic and Political Analysis. International Journal of Humanities and Social Science,Vol. 3 No. 6, Special Issue

52. Melinda A. Zeder(2008). Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact. 105(33): 11597–11604. doi: 10.1073/pnas.0801317105.

53. Messay Mulugeta (2011). Determinates of Agricultural Productivity and Household Food Security Case studies from KuyuWoreda, Central Ethiopia. Germany. LAP LAMBERT.

54. Messay Mulugeta (2012). Resettlement and Food Security Nexus in Ethiopia: A Case Study from Nonno District. PhD Dissertation, Addis Ababa University. Summarized and Published in Journal of Social Sciences and Humanities (EJOSSAH) in 2013

55. Messay Mulugeta, Degefa Tolosa and Gezahegn Abebe (2017). Description of long-term climate Data in Eastern and Southeastern Ethiopia. Journal of Data in Brief, Volume 12, pp 26-36

56. Ministry of Agriculture-MOA. (2011). Agriculture Sector Programme of Plan on Adaptation to Climate Change. Addis Ababa

57. National Disaster Risk Management Commission /NDRMC / (2017). Ethiopia: Humanitarian Response Situation Report No. 16 (November 2017), A product of the Disaster Risk Management Technical Working Group (DRMTWG)

58. National Planning Commission /NPC/ (2016). Growth and Transformation Plan II (GTP II) (2015/16-2019/202), Federal Democratic Republic of Ethiopia, Addis Ababa

59. Negra, Christine (2014). Integrated National Policy Approaches to Climate-Smart Agriculture: Insights from Brazil, Ethiopia, and New Zealand, CCAFS Report No. 11.

60. Nelson (2009). climate change Impact on Agriculture and Costs of Adaptation, Washington, D.C.October 2009.

61. Nelson S, Huyer S. (2016). A Gender-responsive Approach to Climate-Smart Agriculture: Evidence and guidance for practitioners. Climate-Smart Agriculture Practice Brief. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

62. Neufeldt H, Negra C, Hancock J, Foster K, Nayak D, Singh P(2015). Scaling up climate-smart agriculture: lessons learned from South Asia and pathways for success. ICRAFWorking Paper No. 209. Nairobi, World Agroforestry Centre. DOI: http://dx.doi.org/10.5716/WP15720.PDF

63. Ngigi (2009). Climate change adaptation strategies: water resources management options for smallholder farming systems in Sub-Saharan Africa.

64. Nyasimi, Mary, Philip Kimeli, George Sayula, Maren Radeny, James Kinyangi, and Catherine Mungai (2017). Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, Northeast Tanzania, Journal of Climate, MDPI

65. OECD (2015), "The Future of Productivity", Policy Note, July, http://oe.cd/future of productivity

66. Olaf Müller and Michael Krawinkel(2005). Malnutrition and health in developing countries. Aug 2; 173(3): 279–286. doi: 10.1503/cmaj.050342.

67. Oromia Bureau of Finance and Economic Development /OBFED/ (2011). The National Regional Government of Oromia Physical and Socioeconomic Profile of North Shewa Zone and Districts, Finfine Processes and Corresponding Influence on Food Security. In the Journal of Agriculture, Volume 3, pp: 398-417; doi:10.3390/agriculture3030398

68. Parry, M., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fisher. (2004). Effects of Climate Change on Global Food Production under SRES Emissions and Socio–Economic Scenarios. Global Environmental Change 14: 53–67.

69. Parry, M.L. and Carter, T.R. (1989). 'An assessment of the effects of climatic change on agriculture', Clim. Change 15, 95–116.

70. Pearce, D,W. Cline, A. Achanta, S. Fankhauser, R. Pachauri, R. Tol, and P. Vellinga. (1996). The Social Cost of Climate Change: Greenhouse Damage and the Benefits of

Control. In Climate Change 1995: Economic and Social Dimensions of Climate Change, ed. J. Bruce, H. Lee, and E. Haites, 179–224. Cambridge, UK: University Press.

71. Philip (2014). Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. DOI: 10.1080/17565529.2014.951013
72. Robert Mendelsohn (2008) The Impact of Climate Change on Agriculture in Developing Countries, Journal of Natural Resources Policy Research, 1:1, 5-19, DOI:10.1080/19390450802495882
73. Savage, Louise (2006). An Overview of Climate Change and Possible Consequences for Gisborne District. Prepared for Gisborne Civil Defense and Emergency Management Group, New Zeeland
74. Scherr, Sara J., Seth Shames and Rachel Friedman (2012). From Climate-smart Agriculture to Climate-smart Landscapes, Journal of Agriculture & Food Security, Volume 1, No 12, Biomed Central Ltd. Security: Briefing No. 29, Brussels, 27 September
75. Seo and mendelson (2008). An analysis of crop choice: Adapting to climate change in South American farms. vol. 67, issue 1, 109-116.
76. SIDA (2017). Climate Smart Agriculture, Information Brief, March 2017
77. Solomon (2005). Land-use and Land-cover Change in Headstream of Abbay watershed, Blue Nile Basin, Ethiopia
78. Sugden, Jodi (2015). Climate-Smart Agriculture and Smallholder Farmers, The critical Role of Technology Justice in Effective Adaptation, Technology Justice Policy Briefing 2, Practical Action, UK
79. Tanner, T. and Mitchell, T. (2008). Entrenchment or enhancement: could climate change adaptation help to reduce chronic poverty? IDS Bulletin 39(4): 6-15.
80. Temesgen, T. Deressa, Rashid M. Hassan, and Claudia Ringler (2008). Measuring Ethiopian Farmers' Vulnerability to Climate Change Across Regional States, International Food Policy Research Institute, Washington, D C.
81. Tiblets(2018).Household Multidimensional Poverty Analysis in Non-capital Towns of Gulomekada *woreda*, Tigray Region, Northern Ethiopia
82. Trenberth, K. E., (2007). Warmer oceans, stronger hurricanes. Scientific American, July, 2007, 45−51.

83. UNDP (2015). National Human Development Report, Ethiopia: Accelerating Inclusive Growth for Sustainable Human Development in Ethiopia, Addis Ababa
84. UNEP (2011). Food Security in the Horn of Africa: The Implications of a Drier, Hotter and More Crowded Future.
85. UNFCCC (2007). Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries, United Nations Framework Convention on Climate Change
86. UNICEF (2009). Climate Change and Children in the Brazilian Amazon Region
87. United Nation Development Program (UNDP) Ethiopia. (2014). Quarterly Key Economic and Social Indicators. Available at www.et.undp.org accessed on 15th Sep. 2015
88. United Nations (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352), United Nations, Department of Economic and Social Affairs, Population Division
89. United Nations Economic Commission for Africa /UNECA/ (2015). Feeding Africa: An Action Plan for African Agricultural Transformation, UNECA, Addis Ababa
90. Wieczorek, A. M. & Wright, M. G. (2012) History of Agricultural Biotechnology: How Crop Development has Evolved. Nature Education Knowledge 3(10):9
91. Williams, Timothy O., Marloes Mul & Olufunke Cofie, James Kinyangi, Robert Zougmore, George Wamukoya, Mary Nyasimi, Paul Mapfumo, Chinwe Ifejika Speranza, Dorothy Amwata, Snorre Frid-Nielsen, Samuel Partey, Evan Girvetz, Todd Rosenstock and Bruce Campbell (2015). Climate Smart Agriculture in the African Context, United Nations Economic Commission for Africa
92. Woldeamlak, B. (2009). Rainwater Harvesting as a Livelihood Strategy in the Drought-Prone Areas of the Amhara Regions of Ethiopia. OSSREA: Addis Ababa
93. Woldeamlak, B.. (2009). Rainfall variability and crop production in Ethiopia Case study in the Amhara region. In: Proceedings of the 16th International Conference of Ethiopian Studies, ed. by SveinEge, Harald Aspen, BirhanuTeferra and Shiferaw Bekele, Trondheim 2009
94. World bank (2009). Reshaping Economic Geography world development report.
95. World Bank Annual Report (2006). Washington, DC. © World Bank.
96. World Food Programme /WFP/ (2012). Climate Impacts on Food Security and Nutrition: A Review of Existing Knowledge, United Nations World Food Programme, Rome

97. World Vision-Ethiopia (2013). Climate, Community and Biodiversity Project Design Report: Abote Community-Managed Reforestation Project, North Shewa Zone, Oromia Region, Ethiopia, World Vision
98. Yamane, Taro. (1967). Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.
99. Yien (2018). Rural Households' Resilience to Food Insecurity in Lare district, Gambella Region, South West Ethiopia
100. Yohanes, G & Mebratu, K. (2009) Local innovation in climate-change adaptation by Ethiopian pastoralists: PROLINNOVA–Ethiopia and Pastoralist Forum Ethiopia (PFE), Final report. Addis Ababa
101. Zeritu (2018). Determinants of Nutritional Status of Under-five Children in Sebeta Peri-urban Areas, Oromia Special Zone Surrounding Finfinnee, Ethiopia

1: Questionnaire

Dear respondent,

My name is Nazrawit Ayele. I am a postgraduate student at Center for Food Security Studies, College of Development Studies, Addis Ababa University. Currently, I am doing my MSc thesis entitled ‘Climate-Smart Agriculture and Food Security Nexus in Ethiopia: Practices, Adoption Strategies and Technologies in Abote Woreda, Oromia Region, Central Ethiopia.The prime objective of the thesis is to identify climate-smart agricultural best practices and innovations in agricultural production in Abote woreda under which the sample farmers are prepared to take up innovations.You have been selected randomly from different Keeble’s. The responses you give are valuable and will be held in utmost confidentiality and will be used only for the analysis of this research. You will not be identified by name in any case. If you accept to participate in this research, you will be doing so voluntarily and there will not be any monetary returns. You are also free to refuse to respond to any questions you do not feel comfortable answering or to withdraw from the research all together. This interview will take about an hour of your time to respond to the questions.

Thank you in advance for your cooperation.

Questionnaire for basic data collection
Date of interview (Date/Month/Year): ---
Name of interviewer: --
Region: --
Woreda: ---
Kebele: --
Agro ecology: 1. *Dega* 2. *Weynadega* 3. *Kolla*

Demographic characteristics of the respondent

1. Sex: 1. male 2. Female
2. Age in years:---
3. Marital status: 1. Single 2. Married 3. Divorced 4. Widowed
4. Religion : 1.Orthodox 2.Christian 3.Muslim 4.Protestant 5.Catholic
5. Educational level 1. Unable to read and write (Illiterate) 2.Non formal education 3.Formal education(please indicate the highest grade level you attained):-----------
6. Relationships of the respondent to the head of the house hold:1. Head 2. Spouse 3.Child 4.relatives 5.other specify

7. Family size

Age	Male	Female	Total
<15			
15-64			
>64			

8. Household annual income statistics

Income sources	**Income in birr/year/household**	**Remark**
Crop sale		
Livestock sale		
Livestock product sale		
Off farm		
Remittance		
PSNP		
Other		

9. Experience in agriculture in Years ---
10. Do you have access to credit service? 1.Yes 2. No
11. The possession of the livestock of the household:

No	Type	Number
1	Oxen/Cow	
2	Heifers	
3	Hoarse	
4	Mule	
5	Donkey	
6	Sheep	
7	Goat	
8	Poultry	

12. Do you have a regular access to weather information 1. Yes 2. No
13. How far is the nearest market from your residence? ---------------(kilometer)
14. Do you have contact with agricultural extension agents? 1.Yes 2.No
15. If yes for the above question, how many times do you usually meet with extension agents per cropping year? ----------------------------
16. Household crops production and utilization statistics

No	Crop type	Land size in Timad	Amount in Quintals							
			Production in 2009	Sale	Reserve for seed	Gift to others	Post-harvest loss	Obtained through PSNP	Obtained through food	Obtained through remittance
1	Wheat									

2	Maize									
3	Teff									
4	Barely									
5	Sorghum									
6	Pulses (horse beans, peas.									
7	Oilseeds(lin seed, sesame)									
8	Potato									
9	Others									

17. What is/are the major meal/s of the household

No	Meal type	Ingredients with estimate proportion	Mark with 'X'		
			Breakfast	Lunch	Dinner
1	Injera				
2	Wat				
3	Kolo				
4	Nifro				
5	Kita				
6	Bread				
7	Porridge				

18. Do you usually participate farmers field days? 1.Yes 2. No
19. Total farm size of the household in hectares --
20. The slop of the farm land 1. plain 2. hilly 3. steep
21. The level of fertility of the farm land/ 1. Fertile 2. Moderately fertile 3. Less fertile 4. Infertile
22. Does the household possess an irrigated agriculture? 1. Yes 2. No
23. If yes for the above question, what is the size of the irrigated land in *timad* -----------------
24. Livestock products utilization statistics

No	Product type	Estimated utilization(2009)
1	Meat in kg	
2	Butter in kg	
3	Milk in Litter	
4	Cooking oil	
5	Eggs in number	

25. Do you cultivate the following vegetables?

No	Crop type	Yes or No	Production in quintals in 2009E.C
1	Cabbage		
2	Pepper		
3	Carrot		
4	Tomato		
5	Papaya		
6	Garlic		
7	Onion		
8	other		

26. Which form of farming activity does the household carryout for living?

No	Farming type	Yes	No
1	Crop production		
2	Livestock rearing		
3	Mixed farming (crop production and livestock rearing)		
4	From the above farming form, which one is the dominant in the household? Crop production Livestock rearing Mixed farming		

27. Do you apply the following strategies at your farm area?

No	Activities	Yes	No
1	Cultivating different types of crops		
2	Cultivating different varieties of crops		
3	Changing the cropping pattern and sowing date(early or late sowing		
4	Cropping of drought resistance crops		
5	Soil and water conservation practices		
6	Shifting to non-farm activities		
7	Water conservation practice		
8	Planting of trees		
9	Using irrigation water		
10	Using chemical fertilizer		
11	Using improved seed		
12	Using BBM technology		

28. How much fertilizers you used per hectare during last crop year?.........................
29. How much improved seed you used per kilogram during last crop year?......................
30. What is the effect of climate variability on crop production?...

31. What main challenges do you face in your farming related to climate variability?...
32. How do you cope with such challenges?..
33. How the problems of climate change affect your agriculture?

No	Major causes	Mark(X)
1	Flooding	
2	Drought	
3	Late onset	
4	Early onset	
5	Early ending of rainfall	
6	Heavy rainfall	
7	High temperature	
8	Very cold temperature (wurch)	

34. How do you rate the severity of the climate problem?
    1.Very high 2. High 3. Medium 5, Low 5, Very low
35. What do you think should be an acceptable solution for the problem of climate change?..
36. Have there been any attempted solutions to mitigate climate change problem in agriculture for household consumption as far as you know? 1. Yes 2. No
37. If yes, the above questions what were the solutions? ---
38. Did you accept the solution/s at the time? 1. Yes 2. No
39. If you did not accept why? ---
40. If you accepted, why you do? --
41. Will you accept if the same solutions will be introduced in the future? 1. Yes 2. No
42. Are you aware of climate smart agriculture? 1. Yes 2. No
43. Did you or any household member have had information/training on how to use climate smart agriculture? 1. Yes 2. No
44. Are you willing to accept if a new climate smart agriculture practice is introduced? 1. Yes 2. No
45. If 'No' for Question No 44, why---
46. Are you applying the following practice in your agricultural activities?

No	Activities	Mark X(Multiple response is possible)
1	Mulching	
2	Intercropping	
3	Agro-forestry	
4	Crop rotation	
5	Compost	

6	Minimum tillage	
7	Improved seed	
8	Water Harvesting	

47. What necessary conditions you require to accept a climate smart agriculture? ----------------
    ----
48. Will you be willing to accept if a new climate smart agriculture practice is introduced in the future? Are you willing to apply in your farm land? 1. Yes 2. No
49. If 'Yes' or 'No' for Question No 55, why--
    ----
50. Income from livestock and livestock product sale per year? -------------------birr
51. Income from crop sale per year --birr
52. Average distance from main farm land? --birr
53. Number of individuals engaged in off-farm income activities? -----------------------------
54. Off-farm income sources

No	Activities	Mark 'X"	Amount per year
1	Firewood sale		
2	Charcoal sale		
3	Remittance		
4	Others		

55. Household Food insecurity access

S/N	**In the past 30 days,**	**Yes**	**No**
2.1	Did you worry that your household would not have enough food?		
2.1a	If 'yes' how many days within the month?		
2.2	Were you or any household member not able to eat the food kinds you/s/he preferred because of a lack of resources?		
2.2a	If 'yes' how many days within the month?		
2.3	Did you or any household member have to eat a limited variety of foods due to lack of resources?		
2.3a	If 'yes' how many days within the month?		
2.4	Did you or any household member have to eat some foods that you/s/he did not want to eat because of lack of resources to obtain other types of food?		
2.4a	If 'yes' how many days within the month?		
2.5	Did you or any household member have to eat a smaller meal because there was not enough food?		
2.5a	If 'yes' how many days within the month?		
2.6	Did you or any household member have to eat fewer meals/day because there was no food?		
2.6a	If 'yes' how many days within the month?		
2.7	Was there ever no food to eat in your household because of lack of resources to get food?		
2.7a	If 'yes' how many days within the month?		

2.8	Did you or any household member go to sleep at night hungry because there was not enough food?		
2.8a	If 'yes' how many days within the month?		
2.9	Did you or any household member go without eating anything a whole day and night?		
2.9a	If 'yes' how many days within the month?		

Appendix 2: Collinearity test

Variables	*Collinearity Statistics*			
	E***igenvalue***	*Condition Index*	*Tolerance*	*VIF*
(Constant)	10.195	1.000		
X_2: Age of the household head	1.035	3.139	0.169	5.904
X_5:Total Annual Income	0.957	3.264	0.562	1.778
X_6:Number of livestock	0.767	3.647	0.438	2.283
X_7:Number of oxen per household	0.645	3.977	0.479	2.088
X_8:crop production (quintals)	0.425	4.900	0.316	3.161
X_9:Total farm size of household in hectares	0.274	6.097	0.348	2.874
X_{12} : Frequency to agricultural extension agent	0.229	6.672	0.869	1.150
X_{15}:Experience in agriculture in years	0.169	7.759	0.151	6.606
X_{17}: Average distance of residence of the household from main farmland in kms	0.112	9.536	0.601	1.663
X_{18}: The nearest market from households' residence in kms	0.077	11.511	0.605	1.653
X_{20}: Utilization of fertilizers per hectare in the last cropping year in kg per hectare	0.054	13.721	0.519	1.926
X_{21}: Utilization of improved seed per hectare in kilogram in the last crop year	0.030	18.409	0.886	1.129
X_{24}: Number of household members engaging in off-farm activities	0.025	20.298	0.843	1.186
X_{27} :Number of crops- diversity of crops	0.007	37.605	0.535	1.869

Appendix 3: Normality Tests

Variables	***Kolmogorov-Smirnov[a]***			***Shapiro-Wilk***		
	Statistic	***Df***	***Sig.***	***Statistic***	***df***	***Sig.***
X_2: Age of the household head	0.086	200	0.001	0.968	200	0.000
X_4-: Household size	0.122	200	0.000	0.973	200	0.0001
X_5:Total Annual Income	0.160	200	0.000	0.927	200	0.000
X_6: Number of livestock	0.253	200	0.000	0.828	200	0.000
X_7: Number of oxen per household	0.328	200	0.000	0.808	200	0.000
X_8:Crop production (quintals)	0.211	200	0.000	0.898	200	0.000
X_9: Total farm size of household in hectares	0.228	200	0.000	0.894	200	0.000
X_{12}: Frequency to agricultural	0.323	200	0.000	0.637	200	0.000

extension agent						
X_{15}: Experience in agriculture in years	0.118	200	0.000	0.964	200	0.000
X_{17}: Average distance of residence of the household from main farmland in km	0.395	200	0.000	0.333	200	0.000
X_{18}: The nearest market from household's residence in km	0.200	200	0.000	0.882	200	0.000
X_{19}: Utilization of fertilizers per hectare in the last cropping year in kg per hectare	0.286	200	.000	0.812	200	0.000
X_{21}: Utilization of improved seed per hectare in kilogram in the last crop year	0.435	200	.000	0.430	200	0.000
X_{22}: Household participation in field days	0.348	200	.000	0.636	200	0.000
X_{24}: Number of household members engaging in off-farm activities	0.514	200	.000	0.389	200	0.000
X_{27}: Number of crops- diversity of crops	0.188	200	.000	0.914	200	0.000

a. Lilliefors Significance Correction

Appendix 4: Estimates of Parameters of the Logistic Model for Mulching Practices

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*
Agro_ eco			5.996	2	.050	
Agro _eco(1)	9.005	4.542	3.931	1	.047	8145.528
Agro_ eco(2)	13.620	5.919	5.294	1	.021	822330.037
Sex(1)	3.146	1.027	9.377	1	.002	23.242
Age	.035	.083	.182	1	.670	1.036
Education _level			5.818	2	.055	
Education _level(1)	3.221	1.574	4.189	1	.041	25.063
Education _level(2)	3.966	1.645	5.811	1	.016	52.786
HH_ Size	-.031	.116	.071	1	.790	.970
Annual _income	-.001	.001	3.361	1	.067	.999
annual_income_x5	.001	.000	3.214	1	.073	1.001
Number of livestock	-.182	.149	1.502	1	.220	.834
Oxen possession	1.376	.637	4.665	1	.031	3.958
Crop _production	-.148	.067	4.839	1	.028	.863
Total _farm_ size	1.000	.663	2.275	1	.131	2.719
Credit_ access(1)	2.843	1.183	5.772	1	.016	17.159
Extension _agent_ access(1)	2.339	1.140	4.210	1	.040	10.367
Frequency _extension _agent	.046	.029	2.456	1	.117	1.047
Weather_ info _access(1)	-1.572	1.147	1.877	1	.171	.208
Irrigated_ farm(1)	-1.189	1.275	.869	1	.351	.305
Agriculture _ experience	-.029	.075	.147	1	.701	.972
Slop_ farm_ land			1.179	2	.555	
Slop_ farm_ land(1)	-2.057	2.638	.608	1	.435	.128
Slop_ farm_ land(2)	-.800	2.273	.124	1	.725	.449
Distance_ farmland	.645	.267	5.849	1	.016	1.906

Market_ residence_ distance	.935	.494	3.576	1	.059	2.547
Fertility_ farmland			8.422	3	.038	
Fertility_ farmland(1)	-9.961	40192.970	.000	1	1.000	.000
Fertility_ farmland(2)	5.682	2.027	7.855	1	.005	293.608
Fertility_ farmland(3)	5.335	1.892	7.951	1	.005	207.464
Fertilizers_ used	-.003	.005	.228	1	.633	.997
Improved_ seed_ used	.010	.007	2.101	1	.147	1.010
Participation _in_ field_ days	-.552	.928	.354	1	.552	.576
Severity _cc			16.252	4	.003	
Severity _cc(1)	18.210	8754.644	.000	1	.998	80963019.314
Severity _cc(2)	24.125	8754.644	.000	1	.998	30022586380.648
Severity_ cc(3)	17.613	8754.644	.000	1	.998	44587242.212
Severity_ cc(4)	22.982	8754.644	.000	1	.998	9575587980.690
Off farm_ number	-.938	.618	2.298	1	.130	.392
Aware _CSA(1)	-2.239	.991	5.100	1	.024	.107
Training _CSA(1)	1.542	1.345	1.314	1	.252	4.672
Number _ of_ crops (diversity)	1.091	.538	4.115	1	.043	2.978
Constant	-51.351	8754.650	.000	1	.995	.000

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income, annual_income_x5, TLU, Oxen_possession, Crop_production, Total_farm_size, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.

Appendix 5: Estimates of Parameters of the Logistic Model for Intercropping Practices

Variables in the Equation	***B***	***S.E.***	***Wald***	***df***	***Sig.***	***Exp(B)***
Agro_eco			6.853	2	.033	
Agro_eco(1)	-9.931	6.048	2.696	1	.101	.000
Agro_eco(2)	1.646	7.771	.045	1	.832	5.189
Sex(1)	9.814	3.567	7.571	1	.006	18284.863
Age	.467	.245	3.626	1	.057	1.595
Educ_level			.694	2	.707	
Educ_level(1)	-3.133	4.013	.609	1	.435	.044
Educ_level(2)	-2.045	3.685	.308	1	.579	.129
HH_Size	-.048	.199	.057	1	.811	.954
Annual_income_3	1.073	.599	3.209	1	.073	2.923
Number of livestock	-.975	.862	1.280	1	.258	.377
oxen_nu2	1.609	1.344	1.433	1	.231	4.996
tot_production	.475	1.044	.207	1	.649	1.609
farmsize_2	-1.459	1.072	1.851	1	.174	.232
Credit_access(1)	3.493	2.764	1.597	1	.206	32.887
Extention_agent_access(1)	-.923	1.509	.374	1	.541	.397
Frequency_extention_agent	.136	.071	3.610	1	.057	1.145
Weather_inf_access(1)	1.004	1.420	.500	1	.479	2.729
Irrigated_farm(1)	3.109	3.007	1.069	1	.301	22.405
Agri_experience	-.175	.138	1.606	1	.205	.839
Slop_farm_land			3.130	2	.209	
Slop_farm_land(1)	-5.433	3.991	1.854	1	.173	.004
Slop_farm_land(2)	-1.544	3.313	.217	1	.641	.214
Distance_farmland	-.312	.267	1.370	1	.242	.732
Market_residence_disatnce	.767	.727	1.116	1	.291	2.154
Fertility_farmland			1.678	3	.642	

Fertility_farmland(1)	-5.709	40421.233	.000	1	1.000	.003
Fertility_farmland(2)	-28.916	4289.670	.000	1	.995	.000
Fertility_farmland(3)	-26.029	4289.667	.000	1	.995	.000
Fertilizers_used	.031	.011	7.203	1	.007	1.031
Improved_seed_used	-.026	.012	4.540	1	.033	.975
Participation_in_field_days	.450	1.757	.066	1	.798	1.569
Severity_cc			6.362	4	.174	
Severity_cc(1)	.769	3.439	.050	1	.823	2.158
Severity_cc(2)	6.657	3.817	3.042	1	.081	777.861
Severity_cc(3)	-.918	1.847	.247	1	.619	.399
Severity_cc(4)	5.749	3.416	2.833	1	.092	313.933
Offfarm_number	1.123	.999	1.262	1	.261	3.073
Aware_CSA(1)	6.478	2.991	4.692	1	.030	650.901
Training_CSA(1)	-7.996	3.882	4.242	1	.039	.000
no_of_crops	-2.379	1.701	1.957	1	.162	.093
Constant	3.843	4289.683	.000	1	.999	46.672

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.
r2= 0.895 x2 = 220.722 sig. 0.001

Appendix 6: Estimates of Parameters of the Logistic Model for Agro-forestry Practices

Variables in the equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp (B)*
Agro_eco			10.657	2	.005	
Agro_eco(1)	-4.531	4.194	1.167	1	.280	.011
Agro_eco(2)	.896	4.918	10.657	2	.005	2.450
Sex(1)	-.473	.984	.231	1	.631	.623
Age	-.031	.109	.080	1	.778	.970
Educ_level			.810	2	.667	
Educ_level(1)	-.315	1.232	.065	1	.798	.730
Educ_level(2)	.452	1.479	.093	1	.760	1.571
HH_Size	-.031	.130	.059	1	.808	.969
Annual_income_3	-.289	.279	1.070	1	.301	.749
Number of livestock	-.312	.405	.594	1	.441	.732
oxen_nu2	2.174	.768	8.012	1	.005	8.793
tot_production	.021	.594	.001	1	.971	1.022
farmsize_2	.022	.591	.001	1	.971	1.022
Credit_access(1)	.732	1.031	.503	1	.478	2.079
Extention_agent_access(1)	.951	1.058	.808	1	.369	2.587
Frequency_extention_agent	-.017	.030	.312	1	.577	.983
Weather_inf_access(1)	-.030	1.144	.001	1	.979	.970
Irrigated_farm(1)	-6.901	1.934	12.733	1	.000	.001
Agri_experience	.099	.102	.944	1	.331	1.104
Slop_farm_land			3.774	2	.152	
Slop_farm_land(1)	2.281	1.938	1.385	1	.239	9.788
Slop_farm_land(2)	2.831	1.490	3.612	1	.057	16.966
Distance_farmland	-.249	.190	1.718	1	.190	.779
Market_residence_disatnce	.122	.380	.103	1	.749	1.130
Fertility_farmland			2.435	3	.487	

Fertility_farmland(1)	22.167	40192.970	.000	1	1.000	4238289100
Fertility_farmland(2)	2.057	1.876	1.203	1	.273	7.824
Fertility_farmland(3)	2.852	1.836	2.411	1	.120	17.315
Fertilizers_used	-.015	.007	5.270	1	.022	.985
Improved_seed_used	.838	.603	1.934	1	.164	2.312
Participation_in_field_days	1.619	1.039	2.429	1	.119	5.046
Severity_cc			11.909	4	.018	
Severity_cc(1)	7.841	2.485	9.954	1	.002	2543.531
Severity_cc(2)	4.556	1.950	5.456	1	.020	95.162
Severity_cc(3)	3.728	1.862	4.007	1	.045	41.586
Severity_cc(4)	4.165	1.731	5.786	1	.016	64.372
Offfarm_number	-.087	.861	.010	1	.920	.917
Aware_CSA(1)	-1.609	1.358	1.405	1	.236	.200
Training_CSA(1)	4.898	1.918	6.523	1	.011	134.047
no_of_crops	.229	.597	.147	1	.702	1.257
Constant	-9.528	7.735	1.517	1	.218	.000

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.

R2 = 0.546 x2= 135 sig. 0.001

Appendix 7: Estimates of Parameters of the Logistic Model for Crop rotation Practices

Variables in the Equation	***B***	***S.E.***	***Wald***	***df***	***Sig.***	***Exp(B)***
Agro_eco			.000	2	1.000	
Agro_eco(1)	-36.943	56328.291	.000	1	.999	.000
Agro_eco(2)	-41.012	67074.303	.000	1	1.000	.000
Sex(1)	.416	12567.545	.000	1	1.000	1.516
Age	-.153	1231.637	.000	1	1.000	.858
Educ_level			.000	2	1.000	
Educ_level(1)	-1.948	20816.652	.000	1	1.000	.143
Educ_level(2)	-1.048	15584.517	.000	1	1.000	.351
HH_Size	-.881	1809.117	.000	1	1.000	.414
Annual_income_3	-4.805	4554.108	.000	1	.999	.008
Number of livestock	-.145	8445.333	.000	1	1.000	.865
oxen_nu2	-.195	15746.786	.000	1	1.000	.822
tot_production	5.059	10165.986	.000	1	1.000	157.460
farmsize_2	-2.377	8039.492	.000	1	1.000	.093
Credit_access(1)	-15.077	23277.159	.000	1	.999	.000
Extention_agent_access(1)	-.914	22386.651	.000	1	1.000	.401
Frequency_extention_agent	.104	754.225	.000	1	1.000	1.109
Weather_inf_access(1)	16.458	17461.786	.000	1	.999	14041201.514
Irrigated_farm(1)	6.352	26083.633	.000	1	1.000	573.462
Agri_experience	.211	1382.002	.000	1	1.000	1.235
Slop_farm_land			.000	2	1.000	
Slop_farm_land(1)	-2.919	46588.299	.000	1	1.000	.054
Slop_farm_land(2)	1.063	37999.124	.000	1	1.000	2.895
Distance_farmland	-.272	3540.957	.000	1	1.000	.762
Market_residence_disatnce	-1.612	5715.420	.000	1	1.000	.200

Fertility_farmland			.000	3	1.000	
Fertility_farmland(1)	-21.140	59866.764	.000	1	1.000	.000
Fertility_farmland(2)	-5.371	27532.594	.000	1	1.000	.005
Fertility_farmland(3)	-3.733	30710.935	.000	1	1.000	.024
Fertilizers_used	.043	82.373	.000	1	1.000	1.044
Improved_seed_used	.000	216.271	.000	1	1.000	1.000
Participation_in_field_days	-1.471	13652.287	.000	1	1.000	.230
Severity_cc			.000	4	1.000	
Severity_cc(1)	-4.415	23832.595	.000	1	1.000	.012
Severity_cc(2)	-7.406	25790.438	.000	1	1.000	.001
Severity_cc(3)	-.591	30122.824	.000	1	1.000	.554
Severity_cc(4)	-8.836	45767.431	.000	1	1.000	.000
Offfarm_number	-1.353	10013.992	.000	1	1.000	.258
Aware_CSA(1)	.255	22880.022	.000	1	1.000	1.291
Training_CSA(1)	-10.314	20575.245	.000	1	1.000	.000
no_of_crops	4.049	12113.952	.000	1	1.000	57.322
Constant	85.615	88278.791	.000	1	.999	3564

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.
$r2= 0.01$ $x2 = 22.4$ sig. 0.903

Appendix 8: Estimates of Parameters of the Logistic Model for Composting Practices

Variables in the equation	***B***	***S.E.***	***Wald***	***df***	***Sig.***	***Exp(B)***
Agro_eco			.000	2	1.000	
Agro_eco(1)	172.350	15545.883	.000	1	.991	70889
Agro_eco(2)	12.582	21668.934	.000	1	1.000	291199.979
Sex(1)	18.138	3159.182	.000	1	.995	75372851.310
Age	3.115	340.397	.000	1	.993	22.531
Educ_level			.000	2	1.000	
Educ_level(1)	-121.038	7453.864	.000	1	.987	.000
Educ_level(2)	-100.320	6350.902	.000	1	.987	.000
HH_Size	-15.778	504.242	.001	1	.975	.000
Annual_income_3	-23.323	918.979	.001	1	.980	.000
Number of livestock	52.957	2029.978	.001	1	.979	99767521.000
oxen_nu2	127.525	3185.604	.002	1	.968	241740670.000
tot_production	-35.112	1928.848	.000	1	.985	.000
farmsize_2	-95.902	2480.297	.001	1	.969	.000
Credit_access(1)	95.009	2691.043	.001	1	.972	1827033.000
Extention_agent_access(1)	-127.397	4397.828	.001	1	.977	.000
Frequency_extention_agent	-2.904	135.511	.000	1	.983	.055
Weather_inf_access(1)	-50.489	5676.297	.000	1	.993	.000
Irrigated_farm(1)	-293.183	104869.395	.000	1	.998	.000
Agri_experience	2.150	546.660	.000	1	.997	8.581
Slop_farm_land			.003	2	.999	
Slop_farm_land(1)	-81.746	12622.088	.000	1	.995	.000
Slop_farm_land(2)	-228.759	4353.864	.003	1	.958	.000
Distance_farmland	16.278	2530.415	.000	1	.995	11732812.056
Market_residence_disatnce	-7.143	1804.883	.000	1	.997	.001

Fertility_farmland			.002	3	1.000	
Fertility_farmland(1)	-612.185	44912.583	.000	1	.989	.000
Fertility_farmland(2)	-19.265	9753.931	.000	1	.998	.000
Fertility_farmland(3)	183.944	9139.563	.000	1	.984	76922726.000
Fertilizers_used	-1.308	36.811	.001	1	.972	.270
Improved_seed_used	-1.816	28.036	.004	1	.948	.163
Participation_in_field_days	127.798	5088.731	.001	1	.980	31770849.000
Severity_cc			.001	4	1.000	
Severity_cc(1)	-6.561	4429.397	.000	1	.999	.001
Severity_cc(2)	1.036	4369.120	.000	1	1.000	2.819
Severity_cc(3)	268.028	11293.845	.001	1	.981	25293730.000
Severity_cc(4)	166.668	7955.782	.000	1	.983	24155503.000
Offfarm_number	-5.059	1998.131	.000	1	.998	.006
Aware_CSA(1)	-502.912	12322.773	.002	1	.967	.000
Training_CSA(1)	437.282	12483.668	.001	1	.972	81157525.000
no_of_crops	47.926	2018.423	.001	1	.981	65163567.000
Constant	788.547	111895.013	.000	1	.994	

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.

r2= 0.413 x2 = 106.5 sig. 0.001

Appendix 9: Estimates of Parameters of the Logistic Model for Minimum Tillage Practices

Variables in the Equation	***B***	***S.E.***	***Wald***	***Df***	***Sig.***	***Exp(B)***
Agro_eco			.000	2	1.000	
Agro_eco(1)	285.853	34419.719	.000	1	.993	13945554
Agro_eco(2)	101.150	37038.181	.000	1	.998	8488205
Sex(1)	-14.915	8153.241	.000	1	.999	.000
Age	2.325	2159.276	.000	1	.999	10.226
Educ_level			.000	2	1.000	
Educ_level(1)	-55.584	26047.882	.000	1	.998	.000
Educ_level(2)	-32.539	22497.307	.000	1	.999	.000
HH_Size	-1.275	2516.362	.000	1	1.000	.279
Annual_income_3	-5.954	2559.046	.000	1	.998	.003
Number of livestock	-37.814	4200.098	.000	1	.993	.000
oxen_nu2	56.436	8763.088	.000	1	.995	3235035
tot_production	-13.683	7308.562	.000	1	.999	.000
farmsize_2	19.842	6993.307	.000	1	.998	414098813
Credit_access(1)	22.916	12424.355	.000	1	.999	8959863767
Extention_agent_access(1)	-14.706	10415.662	.000	1	.999	.000
Frequency_extention_agent	-1.653	380.817	.000	1	.997	.191
Weather_inf_access(1)	17.225	14353.328	.000	1	.999	30251690
Irrigated_farm(1)	39.570	46200.260	.000	1	.999	15308443
Agri_experience	-1.479	2115.213	.000	1	.999	.228
Slop_farm_land			.000	2	1.000	
Slop_farm_land(1)	184.010	39346.268	.000	1	.996	820975573
Slop_farm_land(2)	136.242	41715.597	.000	1	.997	14767590
Distance_farmland	-15.287	8317.289	.000	1	.999	.000
Market_residence_disatnce	6.394	3629.071	.000	1	.999	598.059

Fertility_farmland			.000	3	1.000	
Fertility_farmland(1)	43.746	46187.335	.000	1	.999	99660244
Fertility_farmland(2)	-3.128	11504.023	.000	1	1.000	.044
Fertility_farmland(3)	-24.122	14895.622	.000	1	.999	.000
Fertilizers_used	.572	91.466	.000	1	.995	1.771
Improved_seed_used	.184	43.364	.000	1	.997	1.202
Participation_in_field_days	53.639	12082.446	.000	1	.996	19739443
Severity_cc			.000	4	1.000	
Severity_cc(1)	-26.977	39119.503	.000	1	.999	.000
Severity_cc(2)	-57.011	48088.219	.000	1	.999	.000
Severity_cc(3)	-84.705	26386.080	.000	1	.997	.000
Severity_cc(4)	-209.177	45870.479	.000	1	.996	.000
Offfarm_number	-8.284	14334.525	.000	1	1.000	.000
Aware_CSA(1)	-44.726	18356.050	.000	1	.998	.000
Training_CSA(1)	72.613	23621.017	.000	1	.998	3432239
no_of_crops	-7.267	11325.023	.000	1	.999	.001
Constant	-350.603	88082.954	.000	1	.997	.000

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.
r2 = 0.724   x2 = 257.7   sig. 0.001

Appendix 10: Estimates of Parameters of the Logistic Model for Improved Seed Practices

Variables in the Equation	B	S.E.	Wald	df	Sig.	Exp(B)
Agro_eco			1.586	2	.452	
Agro_eco(1)	-6.895	5.474	1.586	1	.208	.001
Agro_eco(2)	-6.560	5.903	1.235	1	.266	.001
Sex(1)	-6.371	2.857	4.971	1	.026	.002
Age	-.006	.112	.003	1	.959	.994
Educ_level			7.977	2	.019	
Educ_level(1)	-2.653	1.632	2.645	1	.104	.070
Educ_level(2)	-4.850	1.805	7.220	1	.007	.008
HH_Size	-.333	.194	2.959	1	.085	.717
Annual_income_3	1.335	.471	8.039	1	.005	3.799
Number of livestock	.960	.633	2.296	1	.130	2.611
oxen_nu2	-1.291	.988	1.708	1	.191	.275
tot_production	.139	.757	.034	1	.855	1.149
farmsize_2	-1.536	.808	3.610	1	.057	.215
Credit_access(1)	-3.575	1.471	5.902	1	.015	.028
Extention_agent_access(1)	-2.492	1.723	2.093	1	.148	.083
Frequency_extention_agent	-.022	.039	.338	1	.561	.978
Weather_inf_access(1)	2.506	1.284	3.810	1	.051	12.262
Irrigated_farm(1)	2.382	2.042	1.361	1	.243	10.822
Agri_experience	.085	.107	.628	1	.428	1.089
Slop_farm_land			1.692	2	.429	
Slop_farm_land(1)	1.105	2.932	.142	1	.706	3.020
Slop_farm_land(2)	2.500	2.324	1.156	1	.282	12.177
Distance_farmland	-.193	.200	.931	1	.335	.824
Market_residence_disatnce	-.377	.472	.638	1	.424	.686

Fertility_farmland			.486	3	.922	
Fertility_farmland(1)	-10.905	40192.970	.000	1	1.000	.000
Fertility_farmland(2)	1.172	1.974	.353	1	.553	3.230
Fertility_farmland(3)	.425	1.718	.061	1	.805	1.530
Fertilizers_used	.010	.006	2.848	1	.092	1.010
Participation_in_field_days	-.306	1.066	.083	1	.774	.736
Severity_cc			1.053	4	.902	
Severity_cc(1)	22.948	7590.667	.000	1	.998	9253548906.166
Severity_cc(2)	21.844	7590.667	.000	1	.998	3067490430.587
Severity_cc(3)	21.355	7590.667	.000	1	.998	1880716821.852
Severity_cc(4)	-3.207	10080.153	.000	1	1.000	.040
Offfarm_number	3.822	1.235	9.579	1	.002	45.705
Aware_CSA(1)	2.742	1.646	2.773	1	.096	15.512
Training_CSA(1)	-2.241	1.684	1.770	1	.183	.106
no_of_crops	-.247	.816	.092	1	.762	.781
Constant	-22.234	7590.672	.000	1	.998	.000

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.

r2 = 0.814 x2 = 154 sig. 0.001

Appendix 11: Estimates of Parameters of the Logistic Model for Water Harvesting Practices

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp (B)*
Agro_eco			12.160	2	.002	
Agro_eco(1)	-8.271	3.292	6.312	1	.012	.000
Agro_eco(2)	-4.738	3.766	1.583	1	.208	.009
Sex(1)	-.905	.804	1.266	1	.261	.405
Age	-.132	.078	2.838	1	.092	.877
Educ_level			1.921	2	.383	
Educ_level(1)	1.410	1.018	1.919	1	.166	4.097
Educ_level(2)	1.198	1.134	1.116	1	.291	3.314
HH_Size	.106	.112	.899	1	.343	1.112
Annual_income_3	-.239	.213	1.262	1	.261	.787
Number of livestock	.017	.369	.002	1	.963	1.017
oxen_nu2	-1.455	.632	5.303	1	.021	.233
tot_production	.403	.447	.810	1	.368	1.496
farmsize_2	.568	.427	1.768	1	.184	1.764
Credit_access(1)	1.643	.828	3.939	1	.047	5.169
Extention_agent_access(1)	1.305	.792	2.717	1	.099	3.688
Frequency_extention_agent	.001	.022	.004	1	.950	1.001
Weather_inf_access(1)	-1.718	.869	3.914	1	.048	.179
Irrigated_farm(1)	1.842	1.803	1.045	1	.307	6.312
Agri_experience	.034	.074	.212	1	.645	1.035
Slop_farm_land			.689	2	.709	
Slop_farm_land(1)	.526	1.432	.135	1	.713	1.692
Slop_farm_land(2)	-.259	1.078	.058	1	.810	.772
Distance_farmland	.248	.142	3.038	1	.081	1.281
Market_residence_disatnce	-.303	.284	1.138	1	.286	.738

Fertility_farmland			5.439	3	.142	
Fertility_farmland(1)	19.105	40192.970	.000	1	1.000	198330206.112
Fertility_farmland(2)	-3.060	1.315	5.412	1	.020	.047
Fertility_farmland(3)	-1.556	.969	2.576	1	.109	.211
Fertilizers_used	.002	.005	.171	1	.679	1.002
Improved_seed_used	-.002	.009	.045	1	.831	.998
Participation_in_field_days	-.569	.724	.618	1	.432	.566
Severity_cc			17.475	4	.002	
Severity_cc(1)	-.608	2.190	.077	1	.781	.544
Severity_cc(2)	3.276	2.074	2.497	1	.114	26.482
Severity_cc(3)	4.106	2.092	3.855	1	.050	60.733
Severity_cc(4)	6.061	2.114	8.218	1	.004	428.783
Offfarm_number	-.442	.543	.664	1	.415	.643
Aware_CSA(1)	2.463	1.404	3.078	1	.079	11.744
Training_CSA(1)	-1.411	1.412	.999	1	.318	.244
no_of_crops	-.816	.446	3.351	1	.067	.442
Constant	6.748	5.954	1.285	1	.257	852.402

a. Variable(s) entered on step 1: Agro_eco, Sex, Age, Educ_level, HH_Size, Annual_income_3, TLU_2, oxen_nu2, tot_production, farmsize_2, Credit_access, Extention_agent_access, Frequency_extention_agent, Weather_inf_access, Irrigated_farm, Agri_experience, Slop_farm_land, Distance_farmland, Market_residence_disatnce, Fertility_farmland, Fertilizers_used, Improved_seed_used, Participation_in_field_days, Severity_cc, Offfarm_number, Aware_CSA, Training_CSA, no_of_crops.
r2 = 0.632 x2 = 108.8 sig. = 0.001

Appendix 12: Dependent Variable: Effective use of Improved Agricultural Practices

Parameter	***B***	***SE***	***t***	***Sig.***
Intercept	1.802	.499	3.614	.000
[Agro_eco=1]	-.739	.226	-3.272	.001
[Agro_eco=2]	-.359	.184	-1.949	.053
[Agro_eco=3]	0[a]			
[Sex=0]	.142	.118	1.205	.230
[Sex=1]	0[a]			
[Credit_access=0]	.303	.120	2.527	.012
[Credit_access=1]	0[a]			
[Extention_agent_access=0]	-.033	.135	-.248	.805
[Extention_agent_access=1]	0[a]			
[Weather_inf_access=0]	.102	.121	.842	.401
[Weather_inf_access=1]	0[a]			
[Irrigated_farm=0]	-.063	.172	-.365	.716
[Irrigated_farm=1]	0[a]			
[Slop_farm_land=1]	.051	.242	.211	.833
[Slop_farm_land=2]	.134	.203	.661	.509
[Slop_farm_land=3]	0[a]			
[Fertility_farmland=1]	.102	.640	.159	.874
[Fertility_farmland=2]	.163	.185	.879	.380
[Fertility_farmland=3]	.196	.174	1.129	.260
[Fertility_farmland=4]	0[a]			
[Severity_cc=1]	-.191	.241	-.792	.429
[Severity_cc=2]	.475	.222	2.141	.034
[Severity_cc=3]	.413	.206	2.006	.046
[Severity_cc=4]	.240	.236	1.018	.310

[Severity_cc=5]	0[a]			
[Aware_CSA=0]	.118	.131	.905	.367
[Aware_CSA=1]	0[a]			
[Training_CSA=0]	-.111	.172	-.646	.519
[Training_CSA=1]	0[a]			
Age	.007	.012	.610	.543
Educ_level	.089	.069	1.277	.203
HH_Size	-.008	.016	-.508	.612
Annual_income_3	-.014	.032	-.441	.660
Number of livestock	-.055	.051	-1.070	.286
oxen_nu2	.084	.079	1.062	.290
tot_production	-.055	.072	-.757	.450
farmsize_2	.086	.069	1.239	.217
Frequency_extention_agent	-.003	.003	-.908	.365
Agri_experience	.005	.011	.455	.649
Fertilizers_used	.002	.001	3.394	.001
Improved_seed_used	.003	.001	2.621	.010
Participation_in_field_days	.152	.108	1.407	.161
Offfarm_number	.008	.089	.092	.927
no_of_crops	-.133	.063	-2.115	.036

a. This parameter is set to zero because it is redundant.

a. R Squared = .448 (Adjusted R Squared = .338)

Appendix 13: Food Balance to get average per household or per head

Types	Quantity in Quintals												Available Kcal	
	Prodn	Obtained through Purchase	Obtained through remittance	Obtained through Aid	Obtained through PSNP	**Total Gain (A)**	Gift to others	Sale	Post-harvest loss	Seed reserve	**Total Loss (B)**	Balance (A – B)	Per household	Per head
Wheat	1049.5	0	9	633	0	1691.5	0	177.5	1.15	645	823.65	867.85	2882	403.35
Barley	540.5	0	8	313	0	861.5	27.025	94	28	97	246.025	615.475	2167.02	303.29
Maize	233.5	0	1.75	198.5	0	433.75	2	23.75	4	153	182.75	251	1352.06	189.23
Sorghum	516.5	0	0	381.5	0	898	25.825	53	422	381.5	882.5	15.675	36.07	5.04
Teff	1262	0	63.1	552	0	1877.1	3	470	435.5	579	1487.5	386.6	767.37	107.4
Pulses	586	0	3	441.5	0	1030.5	1	99	30	207	337	694.8	1555.28	217.67
Total	4188	0	84.85	2519.5	0	6792.3	58.85	917.3	920.65	2062.1	3959.42	2831.4	8759.8	1225.98

Source: Survey data for 2017/18 crop year