COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

CLIMATE SMART AGRICULTURAL PRACTICES AND ITS IMPLICATIONS TO FOOD SECURITY IN SIYADEBRINA WAYU *WOREDA*, NORTH SHEWA, ETHIOPIA

BY

TEKESTE KIFLE DEMISSIE

(GSR/2749/10)

JUNE, 2019

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Declaration

I, Tekeste Kifle, hereby declare that this thesis is my original research work and findings. It has not been submitted to any other university for any academic degree. Materials and information other than my own are duly acknowledged and a reference list has been attached. In presenting this thesis in partial fulfillment of the requirements for the degree of MSc. in Food security and Development studies, I grant to Addis Ababa University the non-exclusive royalty free right to archive, reproduce, distribute, and display in any forms including electronic format, via any digital library mechanisms maintained by the University.

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Approval Sheet

As Advisors/ co-advisors of the thesis, we certify that we have read and evaluated the thesis prepared by Tekeste Kifle entitled "*Climate Smart Agricultural Practices and Its Implications to Food Security in Siyadebrina Wayu Woreda, North Shewa, Ethiopia*" and recommend for open defense as fulfilling the requirement for the degree of Master of Science in Food Security and Development Studies.

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As members of the examining board of the thesis open defense, we certify that we have read and evaluated the thesis prepared by Tekeste Kifle entitled "*Climate Smart Agricultural Practices and Its Implications to Food Security in Siyadebrina Wayu Woreda, North Shewa, Ethiopia*" and recommend that it is acceptable as a thesis required for the degree of Master of Science in Food Security and Development Studies.

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Final approval and acceptance of this thesis is contingent upon the candidate's submission of the final copy of the thesis, incorporating all the comments by examining board, to the Council of Graduate studies (CGS) through the Center Academic Committee (CAC) of the center.

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Abbreviations

AEZs:	Agro Ecological Zones
ANRS:	Amhara National Regional State
CAADP:	Comprehensive Africa Agriculture Development Program
CBD:	Convention on Biological Diversity
CRGES:	Climate Resilient Green Economy Strategy
CSA p:	Climate Smart Agriculture practices
CSA:	Central Statistics Agency
CV:	Coefficient of Variability
DAs:	Development Agents
EIA:	Environmental Impact Assessment
EPACC:	Ethiopian Program of Adaptation to Climate Change
EPCC:	Ethiopian Panel on Climate Change
EPE:	Environmental Policy Ethiopia
FAO:	Food and Agricultural Organization
FGD:	Focus Group Discussions
FMNR:	Farmer Managed Natural Regeneration
FS:	Food Security
GDP:	Gross Domestic Product
GHG:	Green House Gas
GTP:	Growth and Transformation Plan
HHs:	Households
IFPRI:	International Food Policy Research Institute
IPCC:	Inter-governmental Panel for Climate Change
KII:	Key Informant Interview
MoA:	Ministry of Agriculture
MoFEC:	Ministry of Finance and Economic Co-operation
Mt CO_2e:	Mega tons of Carbon dioxide Equivalent
NAMA:	Nationally Appropriate Mitigation Actions

NAPA:	National Adaptation Program of Action
NGO:	Non-Governmental Organization
NMA:	National Meteorological Agency
NMSA:	National Meteorological Service Agency
OECD:	Organization for Economic Co-operation Development
OLS:	Ordinary Least Square
PASDEP:	Plan for Accelerated and Sustainable Development to End Poverty
PCI:	Precipitation Concentration Index
PIF:	Policy and Investment Framework of Ethiopia's agricultural sector
RDPS:	Rural Development Policy and Strategies
SACS:	Saving and Credit Services
SLMP:	Sustainable Land Management Program
SPSS:	Statistical Package for Social Science
SSA:	Sub Saharan Africa
SWWBoA:	Siyadeberina Wayu *Woreda* Bureau of Agriculture
TVET:	Technical and Vocational Education Training
UN:	United Nation
UNCCD:	United Nations Convention to Combat Desertification
UNDP:	United Nations Development Program
UNFCCC:	United Nations Framework Convention on Climate Change
WB:	World Bank

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Abstract

Climate change poses a major threat to agricultural production and food security in Ethiopia. Climate-Smart Agriculture (CSA) is one of the solutions that simultaneously address the issues of food security, climate change and agricultural productivity. The objective of this study was to examined trends & variability of temperature and rain fall, identify local CSA practices, and adoptions. The study was conducted mixed methods approach, in which 368 randomly selected households were surveyed, 10 key informants were interviewed, and 6 focus group discussions participants were held. The analysis was employed based on survey data and a binary logistic regression model was used. Findings revealed that highly adopted CSA practices were identified in the study area. Those practices were integrated soil fertility management, crop diversification, crop rotation, and intercropping. Factors determining CSA practices were also explored such as farming system, farm size, access to irrigated farm, access to extension service, distance to market, and access to weather information. The study showed that both maximum and minimum temperature has been increasing and rainfall had fluctuating trend during the last three decades. The conclusion is that a large proportion of respondents were aware of most of the practices, but adoption of the CSA practices examined was very low. Therefore, as a recommendation sensitization of farmers on reality of climate change and the need to adopt CSA practices towards reduction of adverse effect of climate change should continue. Policy and support program should focus on dissemination of CSA practices to a larger proportion of smallholder farmers.

Keywords: Climate smart agriculture; Climate change/ variability; Adoption; Productivity; Food security; Policy

Chapter One

1. Introduction

1.1. Background

Agriculture is important for food security, it produces food eaten by people; and perhaps it provides the primary source of livelihoods for 36 percent of the world's entire workforce. In heavily populated countries of Asia and the Pacific, such assign ranges from 40 to 50 percent (FAO, 2006). Agricultural production in low-income developing countries of Asia and Africa is unfavorably exaggerated by climate change. Agriculture, forestry and fisheries are all susceptible to climate and the production processes are likely to be affected by climate change. However, a food system is vulnerable when one or more of the four components of food security; food availability, food accessibility, food utilization and food system stability.

Agriculture in Africa remains one of the most vulnerable sectors to climate variability and change yet the sector faces various challenges including market system failures and trade barriers, unstable and ineffective socio-economic policies, poor information, infrastructural and financial accessibility, increasing population pressure and resources scarcity, unsustainable agronomic practices and environmental degradation. These challenges are further compounded by the effects of climate variability and change as the sector is mainly rain-fed and climate dependent (Felix *et al.,* 2018). A lot of attention has been shifted towards the development of means and methods of sustaining agricultural activities in Sub-Saharan Africa (SSA) by promoting the use of climate smart agriculture (CSA) among the small holder's farmers through empowerment and capacity building (Branca *et al.,* 2013).

Agriculture is the backbone of the Ethiopian economy (Matousa *et al.,* 2013). This particular sector determines the growth of all other sectors and consequently, the whole national economy. On average, crop production makes up 60 percent of the sector's outputs, whereas livestock accounts for 27 percent and other areas contribute 13 percent of the total agricultural value added. The sector is dominated by small-scale farmers who practice rain-fed mixed farming by employing traditional technology, adopting a low input and low output production system. The land tilled by the Ethiopian small-scale farmer accounts for 95 percent of the total area under agricultural use and these farmers are responsible for more than 90 percent of the total agricultural output. Agriculture accounted for 49% of GDP, 85% of exports, and 85% of employment (UNDP, 2016).

Agriculture in Ethiopia includes crops, livestock, forestry, fisheries and apiculture. It is the most important sector of the national economy and the main source of livelihoods for 85 percent of the population. Yet the agriculture sector in Ethiopia is characterized by low productivity and is unable to meet the food security needs of the people and the country. Ethiopia is characterized by food insecurity emanating from environmental challenges and other structural and institutional factors. Smallholder agricultural production remains low, particularly for cereal crops, which is attributed to erratic and unreliable rainfall; inefficient use by farmers of agricultural resources such as soil amendments and rainwater; limited use of improved seed and fertilizers. Moreover, the dry lowlands experience erratic rainfall at times with very severe droughts, the impact of which, together with land degradation, human population growth and climate change, has greatly impaired the country's economic and social development and its food security status (FAO, 2016).

Ethiopia is a vulnerable to the adverse effects of climate change mainly due to its high dependence on rain-fed agriculture, low adaptive capacity and a higher reliance on natural resources base for livelihood, among others (EPCC, 2015). In terms of livelihood, smallholder rain-fed subsistence farmers and pastoralists are considered to be the most vulnerable to climate variability and change and need interventions to adapt their livelihood systems to changing climatic conditions (Amogne *et al.*, 2018). Ethiopia has a number of policies, strategies and programs pertinent to reducing the vulnerability of the country to climate variability and change as well as agriculture and food security (such as the environmental policy, agriculture and rural development policy and strategy, water resources management policy, national policy on disaster prevention and preparedness, national policy on biodiversity conservation and research, plan for accelerated and sustainable development to end poverty (PASDEP), and integrated watershed management). (Melaku *et al.*, 2016). What remains to be done is creating awareness about the policies as well as promoting their implementation at all levels, for example through mainstreaming of the policies into agricultural extension and the development of national CSA and conservation agriculture implementation manuals (FAO, 2016).

The climate of Ethiopia is characterized by high annual and seasonal variability. Especially the amount and seasonal distribution of precipitation are varying annually and difficult to predict, while the temporal distribution of rainfall during the growing season is an important factor influencing crop yield. Rains may delay by several weeks or stop during critical germination periods, leading to short and long term droughts with crop failures, food shortages, and famines. Furthermore, when occurring during the dry season, rainfall can facilitate the spread of crop diseases (Evangelista *et al.*, 2013). Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern and Southwestern Ethiopia. The rainfall is highly variable both in amount and distribution across regions and seasons. The seasonal and annual rainfall variations are results of the macro-scale pressure systems and monsoon flows which are related to the changes in the pressure systems (IPCC, 2014).

Climate smart agriculture (CSA) is an approach to guide the management of agriculture in the era of climate change. CSA aims to provide globally applicable principles on managing agriculture for food security under climate change that could provide a basis for policy support and recommendations by multilateral organizations, such as UN's FAO. The major features of the CSA approach were developed in response to limitations in the international climate policy arena in the understanding of agriculture's role in food security and its potential for capturing synergies between adaptation and mitigation (Lipper & Zilberman, 2018). According to FAO (2014) CSA is not a new production system it is a means of identifying which production systems and enabling institutions are best suited to respond to the challenges of climate change for specific locations, to maintain and enhance the capacity of agriculture to support food security in a sustainable way.

A study conducted by Melaku *et al.* (2016) at country level in Ethiopia has identified that the adoption rate of CSA practices is low. To support the facilitation for adoption, different key opportunities and challenges are identified and strategic measures were recommended to capitalize on the opportunities and remove the challenges. The study also indicated that there is a gap in research at local level regarding CSA (adoption status, opportunities and challenges) considering the bio-physical, socio-economic and developmental context. These situations ask the need to conduct research at local context in order to strengthen the evidence based decisions for adoption and dissemination of improved technologies across similar farming system (Melaku *et al.*, 2016).

Therefore, CSA and 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. There were insufficient empirical studies based on climate smart agriculture practices in the study area so far to identify the adoption status and challenges in using the practices. Hence, in order to contribute to fill the research gap this study is planning to identify the local climate smart agriculture practices & adoption, trends of climate variability, and the status of agricultural productivity implication to food security in Siyadebrina Wayu *woreda*, North Shewa zone.

1.2. Statement of the Problem

Climate change is a serious threat for agriculture, food security and fight against poverty in SSA in general and in Ethiopia in particular. Crop failure due to erratic climate shocks incidents 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 (UNFCCC, 2014).

According to Temesgen *et al.* (2014) Ethiopia is vulnerable to climate variability and change, and it frequently faces climate related hazards, commonly drought and floods. The variability of rain fall and the increasing temperature were a cause for frequent drought and famine, and putting disastrous impact on the livelihood of the peoples. Alemayehu and Bewket (2016) indicate that in the central highlands, agriculture is predominantly rain-fed and landholdings are about 1.0 ha per household, which is also the national average. Very few households have access to irrigation and non-farm income to supplement their existence. Land degradation and loss of productivity is a major contributor to the widespread poverty and climate change vulnerability of communities in the area.

The National Meteorological Agency (2007) revealed that in Ethiopia climate variability and change in the country is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences. McSweeney *et al.* (2010) indicates that historical climate analysis of Ethiopia's mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade.

Melaku *et al.* (2016) asserted there is a lack of specific and adequate research findings on CSA practices in Ethiopia for the various agro-ecology, soil type, rainfall pattern, farming system, temperature and moisture ranges. A study conducted at national level in Ethiopia has identified that the adoption rate of CSA practices is low and there is a gap in research at local level regarding CSA scoping study. Another study by Williams *et al.* (2015) confirmed that there is no as such a climate smart agriculture practice but the natural, bio-physical, socio-economic, institutional and development situation of the local area determines the context with in which the climate smartness is evaluated and recommended. The gap was due to the newness of the approach, capacity limitation and diversity of the local situations. The concept of the new approaches of climate smart agriculture is not well introduced among the local community and different stakeholders in the study area but few programs are being attempted to be implemented by government and non-government organizations (FAO, 2016).

There is a research gap to the adoption of CSA practices and this study will be identify the gaps like limited access to appropriate farm equipment & tools, farm inputs & materials, and relevant CSA information, knowledge and skills. Hence, to enhance adoption of CSA make an action by providing awareness creation and raising the profile of CSA by promoting success stories and opportunities to smallholder farmers. Therefore, to contribute in filling this gap and meet the local research need the study will aims to identify the status of local climate smart agriculture practices, determining factors, and trends and variability of temperature and rainfall in the study area.

1.3. Objectives of the Study

1.3.1. General objective

The overall objective of this study is to analyze factors that influence adoption of CSA practices and trends and variability of temperature and rainfall (1987 to 2017) in the woreda.

1.3.2. Specific objectives

More specifically, the study aims to:

- examine trends & variability of temperature and rainfall (1987-2017) in the *woreda*

- identify local climate smart agricultural practices in the study sites
- identify the factors that influence the adoption of climate smart agriculture

1.4. Research Questions

This research intended to answer the following basic questions which are derivative from the abovementioned research objectives:

- How farmers are practicing climate smart agriculture activities?
- What are the effects of climate smart agriculture practices to enhance food security in the study area?
- What looks like the status of adoption of climate smart agriculture practices in the study area?
- What factors the uptake of CSA technologies and practices?
- What are the determine factors of climate change variability on crop production & productivity in the *woreda*?

1.5. 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 is no or only small number of research studies have been done on adoption of climate-smart agriculture practices with empirical evidences in Ethiopia. The output of this research will therefore, fill the knowledge gap in local and institutional responses to agricultural productivity in view of climate-smart agricultural practices. It will help to show collaboration among climate-smart agriculture, agricultural production 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 issues between food security and climate-smart agriculture. Policy makers, local administrators and farmers will be benefiting from the output of the study as it will provide them with empirical and scientific evidences.

1.6. Scope of the Study

The scope of the study is limited to Siyadebrina Wayu *woreda* based on crop and livestock production potential and farming activities. The study is to identify local and major factors influencing adoption of CSA practices due to the interest of researcher to conduct research on this under researched and climate change threats to all humanity. The research study used the cross sectional data and applied mixed approach method to triangulate data collection, data analysis, and interpretations. Thus, this research being one of the few preliminary works, it has limitation in generalizing findings to broader scope.

1.7. Limitation of the Study

The limitations of this study was the denial of some household members to respond to some of the questions, especially those related to income and other financial issues relating to privacy, secrecy, confidentiality, and fear of possible increment of taxes. There were also some limiting factors during the process of under taking this study such as limited information on climate variability at temporal scales and their impacts on agriculture at local level, limited access to relevant research literatures in the area, the concept of CSA is relatively new, there is little relevant research conducted so far, hence this study is limited on the number of published and unpublished literature for reference.

1.8. Organization of the Thesis

This thesis is organized into five chapters. Chapter one presents the introduction part (consists of background, statement of the problem, objectives of the study, research questions, significance of the study, scope and limitation of the study, data validity and reliability, and ethical consideration); chapter two provides review of related literature (consists the concept, empirical review, conceptual framework, and policies & strategies); chapter three described the study area, methods and materials (comprises the description of the study area, sampling techniques, sample size, techniques of data collection, techniques of data analysis, and types of data & sources); chapter four gives results and discussions; chapter five presents conclusion and recommendations of the study and finally references and appendices.

Chapter Two

2. Review of Related Literature

2.1. The Concept of Climate Smart Agriculture

The emerging of CSA can be note to have started after the Hague conference where countries met to discuss the adverse effect of climate change and how to mitigate the effects. This conference led to a number of actions and policies to be implemented in order to achieve its objectives (FAO, 2015). Climate Smart Agriculture (CSA), as defined by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. CSA is composed of three main pillars sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing greenhouse gas (GHG) emissions. It is an approach to develop the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2016).

Climate smart agriculture (CSA) is an approach that aims at addressing the challenges of food security and climate change by ensuring there is resilience sustainable systems to increase food productions that may lead to increase of farm income from smallholder farmers (FAO, 2014). In another research CSA defines 'an approach for transforming and reorienting agricultural systems to support food security under the new realities of the world's climate change'. Climate smart agriculture (CSA) technology helps in increasing adaptive capacity through efficiency use of resources and creating an agriculture system that can stand the threats of climate change (Lipper *et al.,* 2014). FAO (2013) defines CSA as agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces or removes GHGs (mitigation) where possible, and thereby enhances the achievement of national food security and development goals.

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address trade-offs and synergies (co-benefits and “triple-wins”) between these three pillars: productivity, adaptation, and mitigation (FAO, 2013).

2.1.1. Climate smart agriculture technologies and practices

In the broader Ethiopian context, climate smart agriculture practices (CSA) and technologies are being implemented within the framework of integrated watershed management, which incorporate a wide range of practices in crop and livestock production including agroforestry, crop rotation and intercropping as well as soil and water conservation measures such as soil/stone bunds, terracing, infiltration ditches, and tie-ridges among others (FAO, 2016). According to CSA (2016) in terms of adoption, most of the climate smart agriculture practices and technologies identified have low to medium on farm adoption rates, despite their potential benefits to adaptation, productivity increase and mitigation efforts. Many of the key barriers to widespread adoption include limited or no access to productive inputs (improved seeds and fertilizer), lack of access to credit, lack of adequate machinery and technology (e.g. row planters), low access to formal markets to sell produce, and limited extension service quality and access particularly in relation to climate smart agriculture.

There is a debate about what technologies and practices should be considered in CSA. Some argue that any agricultural practice that improves productivity or resource use efficiency can be considered as climate smart (Neufeldt *et al.,* 2013). Others look at CSA as complementary for sustainable intensification of agricultural production systems (Campbell *et al.*, 2014). The relationship between conservation agriculture and CSA is also poorly understood, such that any practice under conservation agriculture can be considered as CSA. Many conservation agricultural practices such as minimum tillage, different methods of crop establishment, nutrient and irrigation management and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce GHG emission from the agricultural fields (Sapkota *et al.,* 2015). Similarly, researchers also consider rain water harvesting technologies, use of improved seeds and agriculture insurances as climate smart because they help to cope with extreme climatic events (Altieri & Nicholls, 2013). According to FAO (2013) there are a wide range of agricultural practices and approaches that are currently available at the field level that can contribute to increased production while still focusing on environmental sustainability. The role of these technologies and practices in reducing current as well as future climate change impacts on agriculture and decreasing GHG emission intensity are crucial.

Vermeulen *et al.* (2012) stated a wide variety of CSA options has been proposed to reduce the negative impacts of climate change, build climate resilient agricultural production systems, and harness the benefits of global warming. These options range from a simple adjustment in crop management practices (e.g. changes in sowing time, application of water and fertilizers, tillage practices and inter-cultural operations) to the transformation of agricultural production systems (e.g. change in cropping systems and land uses) to adjust to new climatic conditions in a particular location. These options can also significantly improve crop yields, increase input use efficiencies and net farm incomes, and reduce greenhouse gas emissions wherever possible.

Table 2.1: Benefits of the different CSA practices

CSA Practice	**Benefits**
Irrigation	Farmers can diversify into high value crop production such as horticulture thus reducing risks of crop losses and increasing incomes.
Terracing	Promotes soil and water conservation, especially on steep slopes to reduce soil erosion and increase water percolation.
Traditional and 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.
Agroforestry	Contributes to carbon sequestration, reduces soil erosion and moisture stress, and tree products that are sold for income.
Composting	Composting of crop residues and organic domestic wastes is used for soil fertility and therefore improve crop productivity.

CSA Practice	Benefits
Crop rotation	Used to achieve crop diversity, reduce incidences of pest and diseases of particular crops, improves soil structure and soil fertility through nitrogen fixing crops and reduces soil erosion.
Drought and disease tolerant crop varieties	To avoid crop loss from shorter growing seasons or unreliable rains. This leads to improved productivity and reduced risk of crop failure.
Drought tolerant and deeper rooted fodder grasses and/or legumes	Contribute towards food security and increased livestock productivity. Increased milk production and heavier animal weight leads to more income.
Early planting and use of 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 controls erosion through minimum soil disturbances.
Intercropping	Contributes to nitrogen fixation, improved water retention, and reduced crop failures to drought, pest and diseases.
Management of a tree nursery and tree planting	The trees contribute to soil fertility and help control erosion, provide fuel wood and timber, medicines and fruits.
Livelihood diversification	Diversification of crops, livestock (bee-keeping), trees and irrigation are potential responses to overcoming unreliable rainfall and drought.

Source: Nyasimi et al. (2017)

2.1.2. Climate variability and change

Climate variability: Variations in the mean state and other statistics such as standard deviations, the occurrence of extremes, etc. of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system or from variations in natural or anthropogenic external forcing (IPCC, 2007). Climate change: The most universal definition of climate change is a change in the statistical properties of the climate system over periods of decades or longer, regardless of cause. The term sometimes is used to refer specifically to climate change caused by human activity. For example, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Managing climate variability will help reduce vulnerability and pave the way for adaptation to climate change. Climate information and policies are very fundamental to deal with the impacts of climate variability and change on development and resource management problems. A climate smart agriculture production system would consider understanding systems and clients to enhance institutional capacity for the implementation and up scaling of CSA practices and approaches.

According to IPCC (2007) the term climate variability is often used to denote deviations of climate statistics over a given period of time (such as a specific month, season or year) from the long- term climate statistics relating to the corresponding calendar period. In this intelligence, climate variability is calculated by those deviations, which are regularly term. The term “climate change” is used to refer to changes in the Earth's climate. In the broadest sense, it can be full to mean changes over all time scales and in all of the components of climate, including precipitation and clouds as well as temperature. Climate changes can be caused by both natural forces and human activities. UNFCCC (2014) stated climate change refers to (i) long-term changes in average weather conditions; (ii) all changes in the climate system, counting drivers of change, changes themselves and their sound effects; (iii) only human-induced changes in the climate system.

According to Belay and Getaneh (2016) climate change is a change of climate which is attributed directly or indirectly to human activity. It alters the composition of the global and/or regional atmosphere and natural climate variability observed over comparable time periods. Climatic variability is the type of changes (temperature, rainfall, occurrence of extremes); changes in physical and socio-economic system have been identified in many regions (UNFCCC, 2014). IPCC (2014) reported the global average surface temperature is likely to rise by 1.8 degrees to 4.0 degrees Celsius by 2100. The sea level may rise by 30 to

60 centimeters. Climate variability will increase almost everywhere. Northern latitudes will experience more rainfall, many subtropical regions will see less. Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern and Southwestern Ethiopia.

Deressa (2008) indicates Ethiopian GDP is highly sensitive to variability of rainfall over time and space. Despite high contribution to the overall economy, agriculture in Ethiopia is challenged by many organizational, and climatic factors, of which climate related catastrophes such as drought, floods and irregularities in seasonal rainfall amount and distributions are the major ones. Ngetich *et al.* (2014) stated the threats associated with climate variability in the region have been recognized since the 1960s and several efforts are under way to develop both mitigation and adaptation strategies to cope with this risk, though the outcomes are variable. Climate variability plays an important role in year to year variability in crop production and on the overall economy of the nation.

Kefyalew (2011) explained that Ethiopia is one of the countries in Africa, with current intensity and pattern of climate variability or change, and the resultant adverse effects currently the country is facing, there is no a single social or economic sector in the area which is expected to be free from climate change induced impacts and shocks. Almost all sectors are vulnerable to impacts of climate change. But, the most vulnerable sectors to climate variability and change in the context of Ethiopia includes agriculture (crop production and livestock rearing), water, health, forests, pastures, biodiversity, education and energy. The magnitude of vulnerability and degree of sensitivity to climate change induced shocks and hazards vary from sector to sector. Also in terms of livelihood means, smallholder rain-fed farmers and pastoralists in the country are found to be the most vulnerable to climate change shocks.

World Bank (2011) stated Ethiopia is highly vulnerable to drought, which has caused great economic and social hardship; and climate models predict rising temperatures over the coming decades, likely to impose increasing stress on rain-fed agriculture. Agriculture, forestry, land-use and land-use change account for 74% of GHG emissions. Fuel-wood is the predominant energy source and especially important in Ethiopia, where heating requirements are significant in highland areas in addition to cooking.

Climate change and variability is global concerns, about its impact on agriculture in developing countries has been increasing and some attempts have been made to estimate this impact (IPCC, 2007). Ethiopia is vulnerable to climate variability and change because large segments of its population are poor, dependent on income opportunities that are highly sensitive to the weather, and have low access to education, information, technology, and health services. They have low adaptive capacity to deal with the consequences of climate variability and change. Climate variability particularly rainfall variability and associated droughts have been caused for food insecurity in Ethiopia. Climate change is expected to pose more challenges and to further reduce the performance of the economy (Arndt *et al.*, 2011).

2.1.3. Climate change and food security

The Intergovernmental Panel on Climate Change (2007) and the United Nations Framework Convention on Climate Change (2014) refer to climate change as any change in climate over time whether due to natural variability or as a result of human activity, which alters the composition of the global atmosphere. Thus, climate change can be defined as the slow change in the composition of the global atmosphere, which is caused directly and indirectly by various human activities in addition to natural climate variability over time. Climate change has intensified the risk of catastrophic natural disasters all over the world. Residents of developing countries are particularly vulnerable to these catastrophic risks for three reasons: first, they rely primarily on natural resource dependent income sources for their livelihoods; second, they have few resources with which to adapt to the anticipated change in climatic patterns; and, third, lack of planning and poor management at the central level impedes or delays recovery from climate-related shocks, and in some cases even leads to increased economic and social damage.

According to IPCC (2014) climate change will lead to increases in the frequency and intensity of natural disasters and extreme weather events, such as droughts, floods and hurricanes; rising sea levels and the contamination or salinization of water supplies and agricultural lands; changes in rainfall patterns, with an expected reduction in agricultural productivity in slight areas, especially in sub Saharan Africa, and declining water quality and availability in arid and semiarid regions. Climate change is expected to affect food security in several respects: increased vulnerability to climate change due to dependence on rain-fed agriculture; high levels of poverty; and low levels of human and physical capital as well as generally poor infrastructure.

Climate change, through its spatiotemporal rainfall variability and temperature increase, is exacerbating the challenging 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 of 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).

2.2. Policies and Strategies Relevant to Climate Smart Agriculture

Ethiopia has signed and ratified many of the international conventions and protocols related to climate change and land degradation including the united-nations framework convention on climate change (UNFCCC), the convention on biological diversity (CBD) and the united-nations convention to combat desertification (UNCCD). In Ethiopia there are policies and strategies relevant to CSA includes the climate resilient green economy strategy (CRGES), national adaptation program of action (NAPA), Ethiopian program of adaptation to climate change (EPACC), nationally appropriate mitigation actions (NAMA), rural development policy and strategies (RDPS), growth and transformation plan (GTP), Ethiopia's Agricultural Sector Policy and Investment Framework (PIF), Environmental Impact Assessment Proclamation (EIA), Environmental Policy of Ethiopia (EPE) (Melaku *et al.,* 2016).

All these national and international institutions are supporting policy frameworks that guide and support to conduct research, facilitate to expand the evidence base; enhancing financing options in the process of promoting CSA approach and benefit climate variability vulnerable smallholder farmers and enhance the food security.

2.3. Conceptual Framework

Conceptual framework depicts that diagrammatic representation of adoption of climate smart agriculture practices and productivity. The causes of climate change are interconnected climate smart agriculture practices, agricultural production, and food security. The conceptual framework also indicates that the climate smart agriculture practices and factors that influence adoption of CSA (socio-economic, demographic, and institutional). As shown in the framework, the climate smart agriculture directly linked to agricultural production that increases agricultural productivity and income, food security for households, and diversifies livelihood. Hence, the climate change adversely affects the agricultural production and its implications to food security factors such as low availability, poor access, less utilization and unsustainable food supply. There is a clear linkage between CSA and agricultural production should play a key role in improving agricultural productivity and food security.

According to Malefiya (2017) different climate smart agricultural practices are adopted by various farmers, which enhance the farmer‘s response to climate change. However, adoption of climate smart agricultural practice influenced by socio-economic, demographic and institutional characteristics of the farmers. Demographic characteristics such as age, household size, sex and educational level of household; socioeconomic characteristics such as land and income of household affects farmer decision to adopt climate smart agricultural practices. Institutional factors that affect farmer‘s decision to adopt climate smart agricultural practice includes availability of credit, access of agricultural extension agents and access of information on climate change.

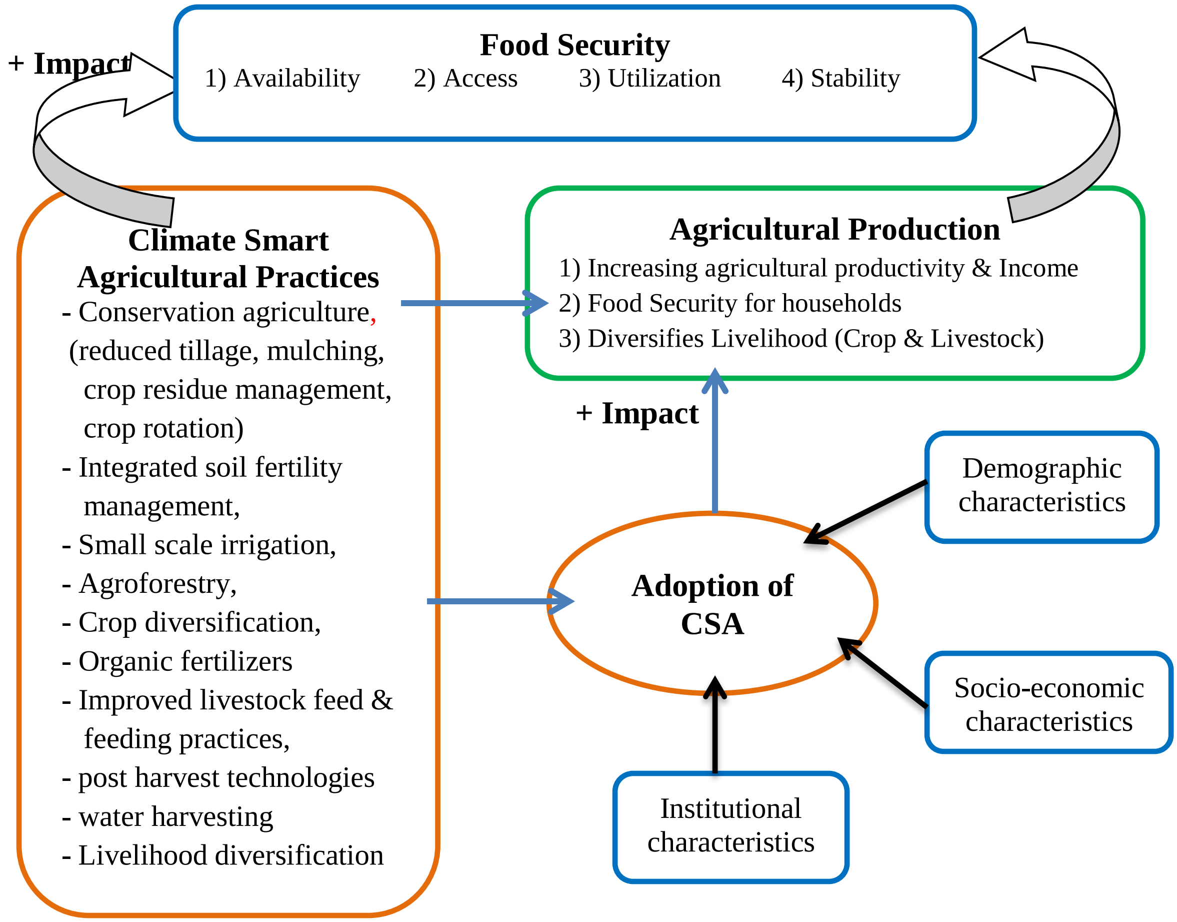

Figure 2.1: Conceptual framework, Source: adapted from FAO (2016)

2.4. Empirical Literature Review

According to Aweke (2017) the adoption levels of some CSA practices and technologies, such as conservation agriculture and agroforestry, among smallholder farmers remain low. Highly fragmented land units are not suited for effective implementation of some CSA practices, while land tenure regimes can significantly hinder credit access for smallholders. Ethiopia has made great effort to issue land certificates to smallholder farmers, and such programs should be accompanied by sensitization of farmers and microfinance providers on the costs and benefits of investing in on-farm climate-smart and sustainable land management practices. CSA includes proven practical techniques such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing and improved water management (Nyasimi *et al.*, 2017).

To improve resilience and to enhance agricultural production and rural livelihoods, systematic response to climate change through adoption of CSA practices and technologies is still very limited in Africa in general and Ethiopia in particular for a host of reasons. In Africa, CSA is used on less than one million hectares, accounting for less than 1% of the total global area under CSA management (Milder *et al.,* 2011).

Empirical studies around the world have identified common variables that affect the probability that smallholder farmers will adopt climate smart agricultural practices. The farmers age, gender, family size, wealth, membership in agricultural organizations, land tenure status and education level have an influence on the adoption of the sustainable practices (Deressaet al., 2009). Adoption rate also determined by subjective variables such as farmer‘s awareness of new practices, personal willingness and over all concern for the problem the practices aims to address (Below et al., 2010).

According to Deressa *et al.* (2009) the commonly reported barriers to the adoption of climate-smart practices are financial constraints, shortages of labor, land and water. Farmers may be generally willing to adopt new practices, but perceive a specific practice to be inadequate, unnecessary, or difficult to incorporate into existing management systems. Two broad categories of barriers or factors that prevent adoption of climate smart agriculture were identified. These are physical or hard ware and non-physical or software barriers. The physical barriers are inputs such as land, human resources, equipment, infrastructure and finances. And the non-physical or software barriers, relates to the institutional, cultural, policy and regulatory environments; information, knowledge and skills; technologies and innovations; and governance among others (James *et al.,* 2015).

According to García *et al.* (2016) all types of capitals (physical, financial, human and social), except natural capital, have a positive and significant effect on the uptake of the livestock production practices. The coefficients of the logistic regressions show that physical and financial capitals seem to have stronger influence on adoption than the other capitals. The adoption rate of climate smart agriculture is low and different opportunities and challenges are identified according to the scoping study conducted in Ethiopia at national level. There is a lack of adequate research findings on climate-smart agriculture in Ethiopia for the various agro-ecological zones, soil types, rainfall patterns, farming systems, as well as temperature and moisture ranges (Melaku *et al.*, 2016).

According to Nyasimi *et al.* (2017) the main constraints to adopt of CSA practices include unpredictability of weather, high farm input cost, lack of access to timely weather information and water resources. Adopting multiple CSA techniques helps in building a sustainable agricultural production system, well resilient to climate related shocks. All the relevant stakeholders should strive to provide farmers with climate smart agriculture related extension messages.

Chapter Three

3. Research Methods

3.1. Description of the Study Area

Location & population

Siyadebrina Wayu is one of the 10 *woredas* of North Shewa zone, Amhara National Regional State (ANRS) of Ethiopia. Siyadebrina Wayu is bordered on the south by the Oromia Region, on the west by Ensaro, on the north by Moretna Jiru, and on the east by Basona Werana district. It is far about 175kms away from Addis Ababa. The study area is located in between 9^0 42’ to 9^0 53’ N latitude and 39^0 08’ to 39^0 17’ E longitude (CSA, 2007). According to the data obtained from the *woreda* administration office and 2007 national census, there are 13 rural kebeles and one urban center (Deneba town) in the *woreda*.

Based on CSA (2013) population projection of Ethiopia for all regions at *woreda* level from 2014 – 2017 report, this *woreda* has a total population 73,166 of whom 37,397 (51.11 %) are males and 35,769 (48.89%) are females; 7,884 or 10.78% are urban inhabitants. The majority of the inhabitants practiced Ethiopian Orthodox Christianity.

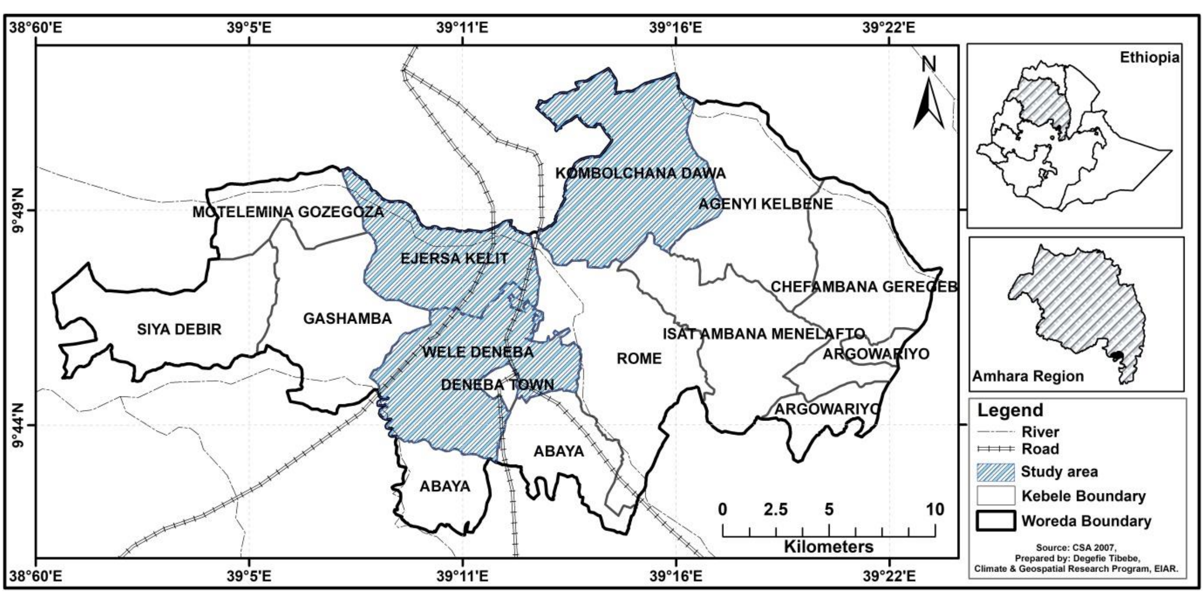

Figure 3.1: Map of Siyadebrina Wayu *woreda* (Source: CSA, 2007 based on national census data)

Physical set up

Land use: according to SWWBoA (2018) report the land use management pattern is as follows. The total land area coverage of the *woreda* is 46,528.4 hectare, out of this 21,789 hectare (46.8%) is arable land, 5585.7 hectare (12%) is used for grazing, 14,092 hectare (30.292%) is covered with shrubs and afforested plants, 5,062 hectare (10.88%) is allocated for residential and infrastructure development.

Soil and vegetation: the soil types in texture of the *woreda* are clay, loam, and sandy; constitutes about 85%, 10% and 5% of the total area respectively. Clay soil is the dominant soil type in the area. The vegetation cover of the *woreda* involves plant trees (eucalyptus tree), shrubs, bushes and wood land (SWWBoA, 2018).

Climate: is one of the elements of the physical environment which has a pronounced impact crop production and human way of life. Temperature and rainfall have a considerable impact in such an agrarian country like Ethiopia and more actually in the study area. The agro-ecological zone of the *woreda* is highland “dega” and the temperature distribution is mainly a reflection of elevation. Rainfall is a major limiting factor in agricultural production in the area. Main rainy season occurs in summer that is between June and August. There was a good rainfall amount and distribution pattern in the area, but for a decade the rainfall pattern was varying due to climate change (NMA, 2018). The average annual rainfall amount varies between 735 to 1187 mm, while the annual mean temperatures vary from 10°C to 22°C.

Economic activities: most of the people in the area are engaged in mixed agriculture. Crop production is entirely rain fed, except in a very specific and small area where vegetables are cultivated based on traditional and small-scale irrigation. The dominant crops in the study area are wheat, teff, faba bean, and lentils. Land preparation is carried on using mainly ox-plowing but tilling by hand occurs in the hilly areas on steeply sloping lands.

According to SWWBoA (2018) report indicated the livestock population number found in the *woreda* were ox (10807), cow (6746), heifer (2009), horse (9536), mule (85), donkey (22071), sheep (6635), goat (9360) and poultry (59088). Domestic animals usually freely graze, but the middle people also purchase animal feed like hay and crop residues from the very poor people.

3.2. Research Approach and Design

The design for this research is non-experimental field based research where the determining variables can be measured in the real context without control, as in the case of experimental one. Descriptive and explanatory research design types were appropriately applied in this research. Descriptive research set out to describe, compare, contrast, classify, analyze and interpret the entities, and the events that constitute the study. Different socio-economic, institutional and demographic characteristics were described at first. Household survey as methods enabled the researcher to describe the phenomena. A cross-sectional analysis across the adoption categories were conducted on the representative sample respondents. Explanatory research is to explore a new universe, one that has not been studied earlier and mainly concerned with causes or factor about some phenomenon. The binary logistic regression model as an explanatory research design was used to determine the magnitude of relationship among the dependent and independent variables under study.

In this study, mixed approach was followed to triangulate the interpretation of data and results to enhance the reliability and validity of findings. In qualitative approach in-depth key informant interview (KII) guide, focus group discussions (FGD) guide, and field observations were tools for data collection. In the quantitative approach household survey on the basis of structured questionnaire interview was conducted by researcher and enumerators during the month of February, 2019. These mixed approach research design was thought to be appropriate to answer the research questions and then met the objectives.

3.3. Sampling and Sample Size Determination

Purposive sampling technique was employed to select the *woreda* and the three targeted study *kebeles* from the total of thirteen *kebeles* in the *woreda* based on their crop and livestock production potential area to show the climate change variability and effect of climate smart agricultural practices on food security.This ensures most representation stratum than the total population and results in more reliable and detailed information. These *kebeles* are Ejersa Kubeti, Wele Deneba, and Kombolchana Dawa. The sample *kebeles* are more cereal productive and high potential areas according to the data obtained from the *woreda* bureau of agriculture.

Based on the information obtained from Siyadebrina Wayu *woreda* administration office, the sampling frame is 4,569 in the three *kebeles*. Then the number of sample households determined to be about 368 (8.02 % of the total households) by using a simplified formula proportion and the sampling method was used simple random sampling. According to Yamane (1967) provides a simplified formula to calculate sample sizes. Assume a 95% confidence level and 5% the desired level of precision.

$$\mathbf{n} = \frac{\boldsymbol{N}}{\mathbf{1}+\boldsymbol{N}(\boldsymbol{e})\mathbf{2}}$$

Where, **n** is the sample size, **N** is the population size, and **e** is the desired level of precision.

Therefore, the researcher used the above formula to determine the size of the sample and the total sample size has been distributed to each sample *kebele* based on the proportion of total number of households in each selected *kebele* as indicated in Table 3.1 below.

Table 3.1: Sample size distribution

Sample Kebeles	Number of farm Households	Proportion of Samples
Ejersa Kubeti	846	68
Kombolcha Dawa	1921	155
Wele Deneba	1802	145
Total	4569	368

Source: SWWBoA (2018)

3.4. Data Sources and Data Collection Tools

3.4.1. Sources of data

Primary data which was collected and captured for the first time for a specific reason and it's gathered from the original sources that are respondents. Primary information were gathered by using different approaches, that includes a household survey, an interview with key informants, focused group discussion and field observations.

Secondary data were collected from existing sources that are, intensive desk review of published and unpublished literatures such as peer reviewed journals, books, conference paper, dissertations and research reports. Most essential data sources for this study were access from Ministry of Agriculture (MoA), National Meteorological Agency (NMA), Bureau of Agriculture North Shewa Zone, International Food Policy Research Institute (IFPRI), Central Statistical Agency (CSA), Ministry of Finance and Economic Cooperation (MoFEC), Food and Agricultural Organization (FAO), Ethiopian Panel on Climate Change (EPCC), and the database of the World Bank.

3.4.2. Tools of data collection

Reliability and validity of the instruments and methodology deal with the quality of data and appropriateness of the methods used. Comprehensive and realistic numerical data, ideas, viewpoints, concepts, definitions, arguments and suggestions were collected so as to enhance the analytical frameworks, and come up with profound research outputs and thoughtful recommendations. While collecting the data, ethical considerations were seriously taken into account to ensure the protection of concern, integrity, anonymity, consents and other human elements of the informants. The research employed household survey questionnaire, FGD, KIIs and field observation as a tools.

Household survey questionnaire

Cross sectional data were administered to sample households by using a questionnaire survey after obtaining the agreement of the respondents as a research ethics. With this technique data related to demography, socioeconomic, biophysical, productivity, technology selection and adoption of CSA practices were collected. Pilot study was done to pre-testing the questionnaire in order to estimate the time needed to complete and implement it. The questionnaire was also translated into Amharic, the local language for simplicity communication with respondents. A random selection procedure was used to obtain samples of individual households from the total HHs. This was helped to get a more representative respondent from HHs with equal probability and thus improve efficiency. Formal interviews of the households were conducted with the close supervision of the researcher and/or trained enumerators.

Key informant interview (KII)

In addition to the cross-sectional data to be carried out, some key persons in sample *kebeles* and the *woreda* were interviewed to obtain supplementary qualitative information on adoption of climate smart agriculture practices. The in-depth interview was focused 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. Purposive sampling technique was employed to identify key informants who were thought to be profoundly well informed in socio-economic, climate and land use in the areas overtime. Ten Key informant interviews were conducted from development agents, *kebele* administrators, crop & livestock production experts, extension agents and Bureau of agriculture heads in the area to obtain relevant information.

Focus group discussion (FGD)

FGD was also used to help to generate data on group dynamics, and allows a small group of respondents to guide by a skilled moderator, to focus on key issue of the research topic. Purposive sampling technique was employed to select the focus group discussant based on knowledge on the present and past environmental, social and economic status of the study area. FGDs carried out with a mix of participants such as household elders, women-headed households, DAs and the youth. Three focus group discussions were organized in each *kebeles* with 5-7 members in a group. The main purpose of focus group discussion was to understand the adoption of climate smart agriculture practices, the perception of climate change and its cause and their responses. The major discussion topics were community awareness of climate smart agriculture, effects of climate change, challenges of crop and livestock production and barriers to employ them effectively.

Field observation

Field observation is used as a supportive technique to collect data that may complement or set in perspective data obtained by other means. Field visits were executed by the researcher to substantiate and enhance the information obtained through other primary and secondary data collection tools. Biophysical and socioeconomic conditions of the area were explored through the field observation. In the time of staying in the study area, the researcher observes topography, vegetation covers, herd management, major development interventions, people’s perception and related things.

3.5. Data Analysis

3.5.1. Descriptive data analysis

Descriptive statistical analysis focuses on the exhaustive measurement of population characteristics. Descriptive statistics which includes frequency distribution, percentage, mean, standard deviation and cross-tabulation were used to summarize and presents demographic, socio-economic and institutional factors. Quantitative data collected by structured survey questionnaire was analyzed using SPSS 23 software. Measure of central tendencies (mean) and measures of dispersion (standard deviation) were the major descriptive techniques that were used to summarize and compare the data. Qualitative data obtained through key informant interview, focus group discussion and field observation. The data organized, summarized, analyzed and interpreted in relation to the survey results.

Both quantitative and qualitative data were used to identify local climate smart agricultural practices, adoption, and effect of climate change on crop production and farmers' adaptation responses in view of its implication to food security in the area.

3.5.2. Multivariate analysis

The study was used the econometric software to analyze the cross sectional data and to perform all the required hypothesis tests by analyzing the regression model. Binary logistic regression model was used to identify and interpret main socio-economic factors affecting adoption of climate smart agriculture practices and its implication to food security in the study area. This model also used to answer the research questions related to the specific objective of determining the effects of CSA and the status of adoption of climate smart agriculture practices.

Binary (binomial) logistic regression is the form of regression used when the dependent variable is a dichotomous and the predictor variables are of any type (Spicer, 2004). The *binary logistic regression model* is a generalized linear model and can be written as:

$\text{Logit}(\pi(x_i)) = \log(\pi(x_i)/1 - \pi(x_i)) = \beta_0 + \beta_1 x_{1i} + \ldots + \beta_p x_{pi}$ or

$\ln(p/1\text{-}p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p$

Where, p = probability of event occurring, p/1-p = odds ratio

The dependent variable in logistic regression is usually binary and can take the value 1 with a probability of success π, or the value 0 with probability of failure $1 - \pi$. This type of variable is called a binary variable. The relationship between the predictor and response variables is not a linear function in logistic regression instead logit transformation of π is used. Consider a collection of P explanatory that the outcome is present to denote by:

$$P(\pi(x)) = \frac{e^{\beta 0+\beta 1X1+\beta 2X2+\cdots+\beta pXp}}{1+e^{\beta 0+\beta 1X1+\beta 2X2+\cdots+\beta pXp}} \quad 0 < p < 1$$

Description of variables

In this study the response (**dependent variable) Y** represents the adoption of CSA practices. Farmers perceived that the adopted CSA practices contributed to both farm income and household food availability. It is measured as a dummy variable, a numeric value 1 if number of farmers adopts CSA, and 0 if no adopters.

The explanatory (**independent variables)** in the regression model are hypothesized to affect the smallholder farmers' adoption of CSA practices and combined effects of various factors such as household demographic characteristics, socio-economic characteristics, and institutional characteristics. Based on the review of related literatures, and past research findings, fourteen potential explanatory variables were considered in this study and examined for their effect on adoption.

Sex of the household head (SEX): If both men and women have more equal participation in agriculture, production can be enhanced the food security status (Elias *et al.*, 2013). It is measured with male coded as 1, and 0 if otherwise. Therefore, it is a dummy variable and expected that sex of the household head may have positive or negative relation to adopt climate smart agricultural practices. Deressa *et al.* (2008) showed that male headed households could be more likely to have access to technologies and climate change information than female-headed households.

Age of the household head (AGE): it is a continuous variable measured in years. The age of the household head represents experience in farming. The older the farmer, the more experienced he/she is in farming and the more exposed to past and present climatic conditions over longer horizons of his/her life spans. According to Umunakwe et al. (2014) younger farmers are more likely to adopt climate smart agricultural practices since they are economical active ages. Hailemariam *et al.* (2013) in their study concluded that an increase in age of the household head reduce the probability of adopting CSA practices, because as farmers advances in age they tend to minimize activities that demand much of their labor and management activities than younger farmers. Maysoon (2015) found that the older farmers are more likely to adopt climate smart agricultural practices. The age of the household head may have a positive or negative effect on adoption of CSA practices.

Household size (HHSZ): represented the total number of family members residing in a home together at the time of the study. The chances for a large household size to be poor are high and therefore add more pressure on the household in terms of the number of people required to feed. It is a continuous variable which indicate the number of person living in the house of farmers. It is measured in adult equivalent and represents the labor input to the farm. In this study, if the majority of the family members are including active labor force age, the household will have enough labor force and the probability to use CSA practices is increase. In such cases family size is expected to have positive effect on adoption (Abraham *et al.,* 2017). Otherwise, the effect becomes negative and the study expected that the size of the family can affect adoption of CSA to climate change either positively or negatively.

Education level of the household head (EDUC): The level of education can enable the household to be open to receive, understand and implement the information relevant for the adoption of a new technology. It is a categorical variable and measured by grade level of the head of the households. Education status was therefore expected to positively correlate with CSA adoption status (Nnadi & Akwiwu, 2008). Education level has a significant effect on adoption of CSA practices, that is, rate of adoption is supposed to be higher with the increases of level of education (Farid *et al.,* 2015).

Farm size (LAND): refers to arable land and it is continuous variable measured in hectares. Large land sizes allow farmers to diversify their crop and livestock options and help spread the risks of loss associated with changes in climate (Farid *et al.,* 2015). Muraoka *et al.* (2014) explained more access to arable land suggests that the household can grow its own food, provided the necessary inputs and resources. Therefore, this study expected to have a positive relation with implementation of climate smart agricultural practices.

Farming experience (FEXPER): experience of the farmers is likely to have a range of influences on adoption of agricultural practices. It is measured in the number of years and taken as a continuous variable. Therefore, this study expected to improve farmers' involvement in seed production and positively affects the adoption.

Farming system (FARMSY): household's carryout for living to assist with access to cash during times of need for food and other household items. It is an increasingly important livelihood strategy in rural households and a categorical variable which indicate the number of household engaged in crop production, livestock rearing, and mixed farming. Practicing farming system will expected to boost positively the adoption of CSA practices status of a household.

Access to irrigation water (IRRIGF): It is measured as a dummy variable, take the value 1 if access water for irrigation, and 0 if otherwise. Irrigation infrastructure reduces the risk of crop failure and the increment in yields can be substantial if properly managed, thus ensuring food security for the household (Sikwela, 2013). Therefore, irrigation may have a positive effect on adoption of CSA practices.

Farm income source (INCOM): It is categorical and takes the value 1 - if the source is only crop sale, 2 - if the source is only Livestock sale, 3 - if the source is from crop and livestock. Income diversification has a great contribution to improve the livelihood of rural household by reducing pressure from agriculture and increasing the household coping natural shocks. This study expected that the more diversified source of income positively influences the decision of the household to adopt climate smart agricultural practices.

Off-farm income (OFARMI): represents the amount of income generated from activities other than crop and livestock production. It is a dummy variable and measured the household head income. It is expected that the availability of off-farm income is positively related with climate smart agriculture practices and household food security status.

Access to agricultural credit (CREDIT): the ability of a household to obtain finance either as formal credit or semi-formal credit, which includes consumption credit (Iftikhar, 2017). It is taken as a dummy variable; if the respondent has access to credit they will code with a numeric value 1, and 0 if otherwise. Credit can help ease cash constraints and allows farmers to buy purchased inputs such as improved seed, Fertilizer, chemicals, livestock feed, and farm equipment (Malefiya, 2017). Thus, this study hypothesized that there is a positive relationship between access of credit and adoption of climate smart agricultural practices.

Access to extension service (EXTEN): It is a dummy variable which takes a visiting time by extension agent. Extension services are an important source of information on farming system and technical support in the context of climate smart agriculture practices and climate change. This implies that farmers with more access to information and technical assistance on agricultural activities have more awareness about the impacts of climate change. More frequent DA visits, using different extension teaching methods like attending demonstrations and field day can help the farmers to adopt CSA practices,. However, all farmers may not have equal access to extension services. Some farmers visit extension agents more frequently while others visit rarely. If the farmers get better extension services, they are expected to adopt CSA practices than others. The extension service expected to have a positive effect on climate smart agriculture practices.

Distance to market (DISMKT): It is a continuous variable measured in kilometer. It refers to the distance from farmer's home to market center. As farmers farm lands get closer to the main road or market center, they can have access to transportation facilities and better support from concerned bodies to their seed multiplication which might increase the use of technology. The residences of farmers' nearest to the market they get a lot of opportunities as compare to the far ones (Malefiya, 2017).

Access to weather information (WEATINF): This is dummy variable indicating 1 if the household head exposed to information on weather/climate change, 0 otherwise. Access to information on weather/climate change through extension agents, meteorological service, media, and social network create awareness are an important precondition for farmers to adopt CSA practices (Abraham *et al.,* 2017). If the farmers get better climate information about seasonal forecasts and climate change, they are expected positively to adopt different CSA technologies than others. Because the availability of better climate information helps farmers make comparative decisions among alternative climate smart agricultural practices.

Table 3.2: Variable code, measurement of explanatory variables and expected effects

Variable code	Description of Variables	Value	Type	Expected sign
SEX	Sex of the household head	Respondent's sex; 1 = male, 0 = female	Dummy	+/-
AGE	Age of the household head	Respondent's age in years	Continuous	+/-
HHSZ	Household size	Number of household members	Continuous	+/-
EDUC	Education level of the household head	Grade level of the household, 1- illiterate, 2- formal, and 3- non-formal education	Categorical	+
LAND	Farm size	Actual farm size in hectares	Continuous	+
FEXPER	Farming experience of HH head	Number of years farming experience	Continuous	+
FARMSY	Farming system carry out for living	Number of household head engaging 1- crop production, 2- livestock rearing, 3- mixed farming	Categorical	+
IRRIGF	Access to irrigation water	1, if the household head has access to water for irrigation, 0 otherwise	Dummy	+
INCOM	Farm income sources of the house hold head	Total household income from 1- crop sale, 2- livestock sale, 3- crop & livestock	Categorical	+
OFARMI	Off-farm Income	1, if the household has sources of off-farm income, 0 otherwise.	Dummy	+
CREDIT	Access to agricultural credit	Household has access to obtain credit or not; 1 = yes, 0 = no	Dummy	+
EXTEN	Access to extension service	1, if the household has access to extension services, 0 otherwise. visiting time by extension agent	Dummy	+
DISMKT	Distance to market center	Distance from farmer's farmland to market center (kilometer)	Continuous	-
WEATINF	Access to weather information	1, if the household exposed to information and 0 if otherwise,	Dummy	+

Source: Adapted from Bernier *et al.* (2015)

3.5.3. Analysis of rainfall and temperature variability

The spatial distribution of the mean annual and monthly rainfall and temperature data was obtained from National Meteorology Agency. The data was used to look into the historical climatic constraints to agricultural productivity by seriously observing the correlation between current climatic variability and agricultural production as well as livelihood systems and coping strategies across the *woreda*. The analysis of climatic condition uses various mathematical procedures and techniques. Analysis of the rainfall at annual and seasonal time scales involved characterizing long term mean values and calculation of indices of variability. The coefficient of variation (CV) and precipitation concentration index (PCI) were used as statistical descriptors of rainfall variability. PCI was computed to look into the level of rainfall distribution (concentration or uniformity) throughout months of a year. Heterogeneity of monthly rainfall amount was investigated using the PCI (Bewket, 2009). The PCI values described as follows, as in Oliver (1980), De Luis et al. (2011) and Mahlet (2013):

$$PCI_{annual} = \frac{(\Sigma p_i^2)}{(\Sigma p_i)^2} \times 100$$

Where, PCI = precipitation concentration index

Pi = is the rainfall amount of the i^{th} month of a year

Σ = summation over the 12 months.

According to Oliver (1980) the precipitation concentration index for annual scale calculated and if PCI values will be:

< 10 = indicates uniform monthly distribution of rainfall

11 – 15 = indicates moderate precipitation concentration

16-20 = indicates irregular distribution

> 20 = indicates a strong irregularity i.e. high precipitation concentration

Rainfall and temperature variability over a period of time was analyzed by calculating the coefficients of variability (CV) of the rainfall and temperature values at different time scale. The CV of annual and monthly rainfall and temperature calculated by using the following formula as Agrawal (2010):

$$CV = \frac{\sqrt{\dfrac{\Sigma f(xi - \bar{x})^2}{n}}}{\bar{x}} = \frac{\sigma}{\bar{x}}$$

Where, **x̄** - mean annual rainfall in mm, **n** – number of years for which the rainfall data are available, **xi** - annual rainfall (mm) of the year (i) of a given station, and **σ** - standard deviation.

According to NMSA (1996) the annual rainfall variability of an area with coefficient of variation, where, CV < 20% is less variable, CV is between 20% and 30% moderately variable and CV > 30% is high variable.

The analysis of rainfall and temperature involved characterizing long-term mean values, calculations of indices of variability and trend at annual and seasonal time steps. Standard anomaly was calculated to assess rainfall and temperature variability. **SRA = Pt – Pm/σ** Where, Pt is annual (rainfall or temperature) in year t, Pm is long-term mean annual (rainfall or temperature) over the period of observation and σ is standard deviation of rainfall.

Mann-Kendall test as described by Sneyers (1990) was used to detect trends. The significance level of the slope was estimated using Sen's method. Mann-Kendall test and Sen's method are less affected by outliers (salmi *et al.*, 2002). The study applied Agnew & Chappel's (1999) drought severity assessment method. This method provides a more elaborate classification of drought magnitudes. The model differentiated drought severity into four scales: extreme drought (S < -1.65), severe drought (-1.28 > S > -1.65), moderately drought (-0.84 > S > -1.28) and no drought (S > -0.84).

Chapter Four

4. Results and Discussions

4.1. Profile of Respondents

As shown in Table 4.1, the respondents of households in each *kebele* described the sex of household head. From the total household heads included in the sampling, 35 (9.5%) were female-headed and 333 (90.5%) were male-headed households. Therefore, male-headed households were in a better position to pull more labor force than the female-headed ones and they also made decisions on farming activities.

Table 4.1: Distribution of Sample Households by kebele and sex

Sex	*Kebele*			Total	Percent
	Ejersa Kubeti	Kombolcha	Wele Deneba		
Male HHs	62	142	129	333	90.5
Female HHs	6	13	16	35	9.5
Total	68	155	145	368	100

Source: Field survey data (February, 2019)

Age could determine CSA practices and adoption rate among the farming households. Accordingly the respondents age was classified based on the Santrock (2011) age group classification i.e. from 20-40 young, 41-60 adult and >60 are elders. In this regard the age distribution of the respondents ranged from 21- 65 years and the average age was 44 years. Table 4.2 shows the respondents age between 20-40 are 128 (88.89%) of the total male headed households and the remaining 16 (11.11%) are female headed households, the respondents age between 41-60 are 179 (91.79%) male headed households and 16 (8.21%) are female headed households, and greater than 60 years old are 26 (89.66%) male headed households and the remaining 3(10.34%) are female headed households. However, 50% of the respondent's age was below the average. So, productive age groups are higher than the non-productive age groups, the probability of a household to be in shortage of food would be less, provided that the area provides good working atmosphere and production potential.

Table 4.2: Distribution of Sample Households by age group

Age	Frequency			Percent	
	Male	Female	Total	Male	Female
20 - 40	128	16	144	88.89	11.11
41 - 60	179	16	195	91.79	8.21
> 60	26	3	29	89.66	10.34
Total	333	35	368	90.49	9.51

Source: Field survey data (February, 2019)

The survey result in the Table 4.3 indicates that out of the total household size in the study area 54.5% of the respondents are male and 45.5% are female. The average household size of the respondents is 5 and the absolute size of the respondents ranged from 1 to 12 members. As it can be seen from the same table the marital status of the household head showed that 89.2% of the respondent are married, 4.9% single, and 5.9% of the household heads were divorced & widowed. In terms of religious composition, 97.1%, 0.8%, and 0.3% of the survey households were Orthodox Christianity, Muslim, and Protestant respectively. As household size increases, obviously the number of mouths to feed from the available food increases. Hence, it is hypothesized that household size and food insecurity are positively related.

Table 4.3: Distribution of household size, and marital status by kebele and sex

	Kebele						Total			Percent	
	Ejersa		Kombolcha		Wele						
	M	F	M	F	M	F	M	F	Total	M	F
Household Size	191	140	423	352	414	366	1028	858	1886	54.5	45.5
Marital status											
Single	1	0	6	1	8	2	15	3	18	83.3	16.7
Married	59	2	135	8	119	5	313	15	328	95.4	4.6
Divorced	1	0	0	1	0	0	1	1	2	50.0	50.0
Widowed	1	4	1	3	2	9	4	16	20	20.0	80.0
Total	62	6	142	13	129	16	333	35	368	90.5	9.5

Source: Field survey data (February, 2019)

As shown in Table 4.4, more than 26.9% of the respondents stated that they were first cycle primary school, 11.4% of the respondents were second cycle primary school, 5.4%, 0.5%, and 0.3% of the respondents were completed high school, preparatory, and TVET & above respectively. However, out of the total respondents 55.5% of the household heads were illiterate with no formal education. Thus, they are unable to read and write. In general 44.5% of the respondents were literate with formal education. This indicates that a majority of smallholder farmers have appreciable formal knowledge to understand and implement climate-smart agricultural technologies promoted in the area when compared to illiterate ones. The educational level of farmers has a direct link with the perception to climate variability. Farmers with relatively higher education levels have opportunities to get information from schools, environmental clubs and other sources of information. Thus farmers with higher educational level have better perception than farmers with lower levels of education.

Table 4.4: Distribution of Sample Households by educational status and sex

Educational status	Frequency			Percent		
	Male	Female	Total	Male	Female	Total
Illiterate	175	29	204	52.6	82.9	55.5
First cycle primary school (Grade 1-4)	99	0	99	29.7	0.0	26.9
Second cycle primary school (Grade 5-8)	38	4	42	11.4	11.4	11.4
High school (Grade 9-10)	18	2	20	5.4	5.7	5.4
Preparatory (Grade 11-12)	2	0	2	0.6	0.0	0.5
TVET and above	1	0	1	0.3	0.0	0.3
Total	333	35	368	100	100	100

Source: Field survey data (February, 2019)

As indicated in Table 4.5, about 50.5% of the respondents had > 1.5ha of farmland, while about 25% have 1.01 – 1.5ha of farm land and 24.5% of the respondents have less than 1ha of farmland. According to Amadou et al. (2015), farmers with high experience are more perceive climate change. This can be as a result of their ability to understand the farming systems better and respond accordingly. In line with his argument in the study area about 59.5% of the respondents have > 20 years in farm experience, 29.4% of the respondents have 11 – 20 years, and 11.1% of the respondents have less than 10 years' experience in agriculture.

Table 4.5: Distribution of farm size and farm experience of the households by kebele & sex

Kebele	Sex	Farm size in Ha.				Farm Experience in years			
		0.25-1.00	1.01-1.5	>1.5	Total	1-10	11-20	>20	Total
Ejersa	Male	8	12	42	62	3	26	33	62
	Female	0	4	2	6	2	0	4	6
Kombolcha	Male	44	39	59	142	18	36	88	142
	Female	4	4	5	13	1	7	5	13
Welle	Male	28	28	73	129	14	35	80	129
	Female	6	5	5	16	3	4	9	16
Total		90	92	186	368	41	108	219	368

Source: Field survey data (February, 2019)

In permanent agricultural systems, soil fertility is maintained through applications of manure, other organic materials, inorganic fertilizers, lime, and the inclusion of legumes in the cropping systems. From the sample households, about 98.1% are well recognized the slope of land in the study area is plain. 79.6% of the respondents recognize the level of fertility of the farm land is moderately fertile as indicated in Figure 4.1 and 4.2. The result in the study area shows the respondents doesn't possess an irrigated farm is 96.2% (354) and 3.8% (14) of the respondents used furrow irrigated farm.

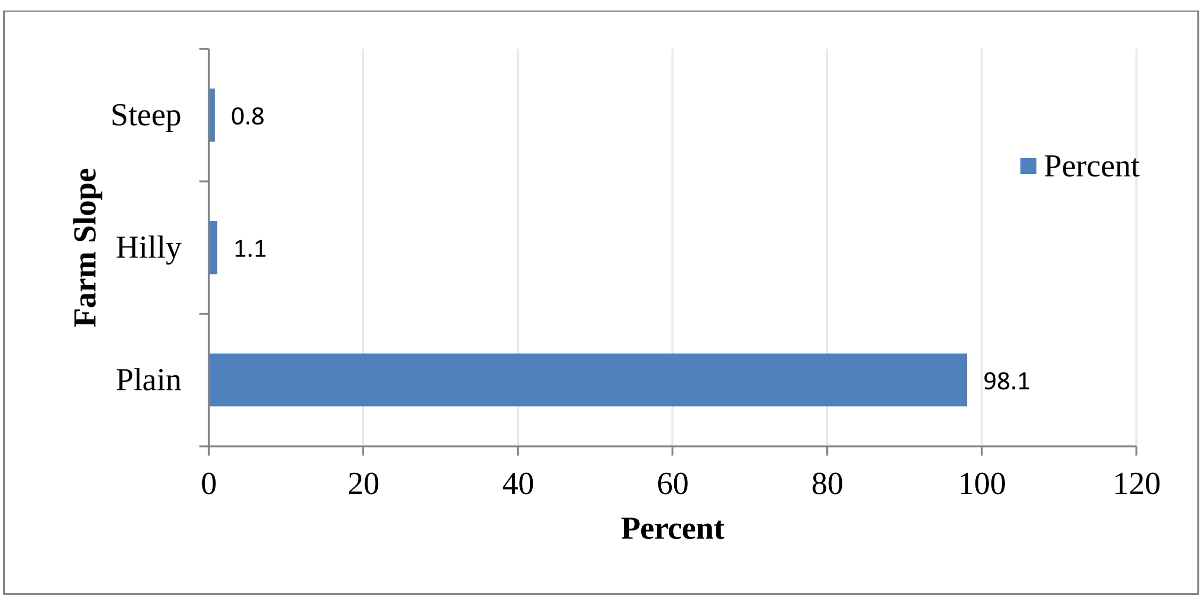

Figure 4.1: Slope of land in S. Wayu woreda (Source: Field survey data (February, 2019))

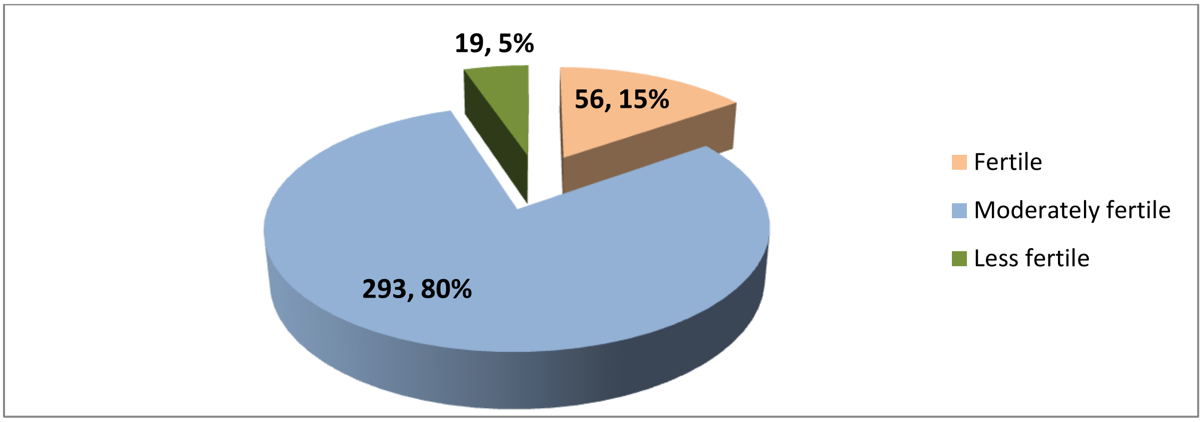

Figure 4.2: Perception of farmer's level of farm land fertility in Siyadeberina Wayu woreda (Source: Field survey data (February, 2019))

According to Wiebe (2003) agricultural productivity is the measurement of the quantity of agricultural output produced for a given quantity of input or a set of inputs (such as tons of wheat per acre of land). The quantities of output relative to the quantity of inputs are the conventional measures of productivity. If the output growth rate exceeds the growth rate in the use of inputs, then productivity is positive. The major crops in the study area are wheat, teff and pulses (Faba bean, field pea, lentil, and chickpea). As can be seen from Table 4.6 the cross sectional data shows that the productivity of wheat, tef, faba bean, field pea, lentil, and chickpea are 5.33, 2.80, 2.47, 1.69, 1.30, and 2.65 tons per hectare respectively. According to CSA (2017) the national agricultural productivity of wheat, tef, faba bean, field pea, lentil, and chickpea are 2.74, 1.75, 2.11, 1.67, 1.47, and 2.06 tons per hectare respectively. Therefore, in the study area wheat and teff crops have a good performance when it compares to national productivity. This indicated that the farmers adopted soil fertility management and crop diversification climate smart agriculture practices.

Key informants and Focus group discussant also respond wheat is the most produced/planted crop in the study area. Therefore, Denda'a and Hidase are the most important varieties of wheat for food security. Because of high productivity, low straw content, high disease resistance, suitable for all highland soil and temperature.

Table 4.6: Agricultural productivity in Siyadeberina Wayu *Woreda* in 2017/18 Crop Season

Crop Type	Improved seed with Fertilizer			Local Seed With Fertilizer			Total		
	Ha.	Yield (Tons)	Tons/ Ha.	Ha.	Yield (Tons)	Tons/ Ha.	Ha.	Yield (Tons)	Tons/ Ha.
Wheat	4618	23639.9	5.12	5114	28224.8	5.52	9732	51864.7	5.33
Tef	1001.2	1158.2	1.16	4001	12851.5	3.21	5002	14009.7	2.80
F. Bean	293.7	141.8	0.48	1647	4649.0	2.82	1941	4790.8	2.47
F. Pea	0	10.4	0.00	152	246.1	1.62	152	256.5	1.69
Lentil	585.5	1380.4	2.36	2873	3117.8	1.09	3458	4498.2	1.30
Chickpea	45.5	126	2.77	100.5	261.2	2.60	146	387.2	2.65
Barely	0	0	0.00	268	655.6	2.45	268	655.6	2.45
Sorghum	0	0	0.00	193	560.1	2.90	193	560.1	2.90
Nug	0	0	0.00	6.5	4.9	0.76	6.5	4.9	0.76
Linseed	0	0	0.00	29	14.5	0.50	29	14.5	0.50
Fenugreek	0	0	0.00	106	191.2	1.80	106	191.2	1.80
Vegetable	21.9	262.31	11.98	126.5	972.5	7.69	148.4	1234.9	8.32

Source: SWWBoA annual report (2018)

There were some challenges faces when farmers do agricultural operations in the *woreda*. According to Key informants and Focus Group Discussants challenges happen for crop productivity such as climate variability, market access, agricultural credit service, pest & diseases, agricultural inputs, traditional land preparation, lack of machinery & labor during harvesting time, and post-harvest (lack of mechanization, store facility, and processing machine).

The household survey results indicated in Table 4.7 the mean livestock number of the respondent household owns 6.79 chicken, 5.3 sheep, 3.68 cattle, 2.91 goats, and 2.27 pack animals. This indicates that any improvement in livestock ownership position of the respondents may improve the food security status of the community provided that other environmental and socio-economic attributes.

Table 4.7: Average number of livestock per household in the study area

Type	Ox/Cow	Heifers	Horse	Mule	Donkey	Sheep	Goat	Chicken
Frequency	364	262	159	1	361	306	33	278
Minimum	1	1	1	2	1	1	1	1
Maximum	7	4	5	2	5	20	7	30
Mean	2.82	1.25	1.20	2.00	1.78	5.30	2.91	6.79
Total LS No.	1026	328	191	2	643	1623	96	1889

Source: Field survey data (February, 2019)

Table 4.8 illustrates farming system and income sources of the respondents. About 80.7% and 19.3% of the respondents carried out mixed farming system and only crop production respectively. The main source of income for household about 82.07% obtained from sales of crop production and 17.93% of the household income getting from both crop & livestock production. While 29 (7.88%) households were reported off-farm is as a sources of income and 339 (92.12%) of the respondents did not utilize off-farm resources as an income.

In a similar manner in the study area the distance between the farm site and the market is assumed to be determining factor for adoption of the climate smart agriculture practices. The minimum distance from the farmers' site to the nearest market is 200 meter and the maximum distance is 20 km. Where the distance increases the marketing linkages for the farm inputs and output would not be strong and have a negative relationship. The result of the study shows the mean and standard deviation of the distance to market is 5.9 and 3.9 respectively.

Table 4.8: Farming system and off-farm income sources by kebele & sex

	Kebele						Total			Percent		
	Ejersa		Kombolcha		Welle							
	M	F	M	F	M	F	M	F	Total	M	F	Total
Farming system												
Crop production	0	0	8	0	58	5	66	5	71	19.8	14.3	19.3
Crop & Livestock	62	6	134	13	71	11	267	30	297	80.2	85.7	80.7
Sources of income												
Crop sale	62	6	108	10	105	11	275	27	302	82.58	77.14	82.07
Livestock sale	0	0	34	3	24	5	58	8	66	17.42	22.86	17.93
Off-farm Income												
Yes	13	1	8	0	7	0	28	1	29	8.41	2.86	7.88
No	49	5	134	13	122	16	305	34	339	91.59	97.14	92.12

Source: Field survey data (February, 2019)

The result from the household survey showed in Table 4.9 the majority of the respondents about 56% obtained access to credit service from various sources and 44% does not have access to credit service. Access to credit for farming purposes did not significantly differ between male headed and female headed households. Generally, most of the loan amounts received was used for the purposes of improving farm production such as purchase of farm inputs (89.3%), purchase of livestock (6.3%) and purchase of land (3.9%). Access to credit services enhances the probability of a smallholder farmer to adopt climate smart agriculture practices that improve food security and income. This result related with the findings of Amao and Ayantoye (2015), who proved that access to credit, can be used to expand farm production through creating the financial capacity to purchase and use of modern improved agricultural inputs. New technologies expected at improving farm productivity may require additional finances through credit facilities for their effective implementation.

Table 4.9: Access to credit service and purpose of loan by sex

	Sex			Percent		
Access to credit service	M	F	Total	M	F	Total
Yes	185	21	206	55.6	60.0	56.0
No	148	14	162	44.4	40.0	44.0
Total	333	35	368	100.0	100.0	100.0
The main purpose of the loan						
Purchase farm inputs (e.g. seeds, fertilizers)	163	21	184	88.1	100.0	89.3
Buy livestock	13	0	13	7.0	0.0	6.3
Buy land	8	0	8	4.3	0.0	3.9
Construction of farm structures	1	0	1	.5	0.0	.5
Buy machinery and equipment	0	0	0	0.0	0.0	0.0
Payment of labor costs	0	0	0	0.0	0.0	0.0
Total	185	21	206	100.0	100.0	100.0

Source: Field survey data (February, 2019)

The survey result in the Table 4.10 indicates 97.8% of the respondents have agriculture extension service contacts. This result shows most of the respondent are extension service users. According to the survey report 81.5% of the total sample households were participated on farm field day for experience sharing and the remaining 18.5% respondents reported they did not make any extension contact for participating on farm field day. Some respondent farmers participate in adoption of the improved practices despite their non-contact with surrounding farmers for experience sharing. From the results the average frequency of meeting with agricultural extension agents is 5.57 and the contact time with extension agents is minimum 1 and maximum 32.

Table 4.10: Access to extension agents and participation of farmer’s field day

		Frequency	Percent
Contact with agricultural extension agents			
	Yes	360	97.8
	No	8	2.2
	Total	368	100
Participation of farmers field day			
	Yes	300	81.5
	No	68	18.5
	Total	368	100

Source: Field survey data (February, 2019)

As shown in Figure 4.3, 75.5% of the respondent reported access to weather information and 24.5% of the respondents do not have access to appropriate information or are unable to fully utilize existing information.

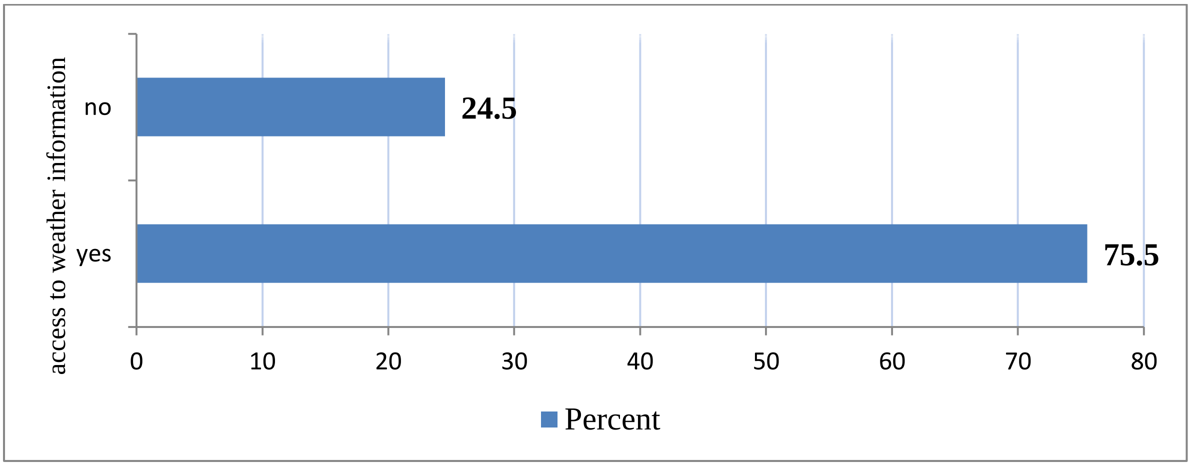

Figure 4.3: Weather information (Source: Field survey data, February, 2019)

Farmers' perception on climate changes and its impacts on the agricultural production have resulted in the adjustment of agricultural calendar and adoption of different adaptation strategies. Significant association between the observed changes in agricultural practices and household gender were observed among small holder farmers in semi-arid and sub-humid regions (Kalungu, Filho, & Harris, 2013). The perception of household's climate change information influenced different economic and livelihood attributes. Figure 4.4 indicated that 67% of the respondents have low information, 32% of the respondents' medium information, and only 1.6% of the respondents obtain high information and adoption level through different sources.

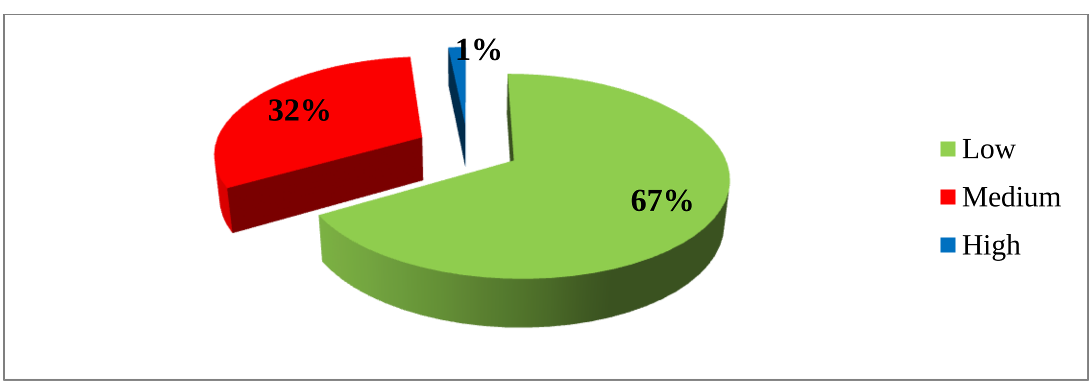

Figure 4.4: Climate change information (Source: Field survey data, February, 2019)

With regard to perceptions of climate change the key informants respond the climate change effects are reducing of crop production and livestock, extortion of desertification, drought, high temperature, flood, high or low rain fall, food insecurity, disturbance of eco-system, losses of some crop varieties, crop pests and diseases, disease occurred on animals, lack of awareness on agricultural practices and increase land degradation. The key informants also suggests to mitigate and adoption of climate changes some of farming practices are implemented in the study area such as using organic fertilizer, re use of wastes, conservation of soil and water, afforestation, environmental production, and natural resource conservation.

4.2. Analysis of Climate Variability

Ethiopian agriculture is highly exposed to climate variability, and in particular to drought and related heat stress. There are close correlations between changes in rainfall, agricultural productivity, GDP and broader human well-being. Global circulation models predict an increase in temperature of 1.7 to 2.1 degrees Celsius by 2050. The combination of higher temperatures and more unpredictable rains has negative implications for the length and reliability of the growing season (World Bank, 2011).

4.2.1. Trends of temperature

According to the National Meteorological Agency (2007) in Ethiopia climate variability and change in the country is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences. The Ethiopian climate is also characterized by a history of climate extremes, such as drought and flood, and increasing and decreasing trends in temperature and precipitation, respectively. The average annual minimum temperature over the country has increased by about 0.37℃, whereas, average annual maximum temperature has increased by about 0.1℃ every decade (NMA, 2007).

Temperature distribution in the study area was characterized by a general trend of increased and annual variability. Temperature is one of the elements that determine weather condition as well as climate of an area. It is recorded as maximum and minimum daily, monthly and annual temperatures. According to the data obtained from NMA the maximum annual average temperature ranges between 20.76ºC and 22.09ºC and the minimum annual average temperature ranges between 8.89ºC and 10.09ºC in the past three decades, while the average temperature of the *woreda* under study ranges between 14.80ºC and 16.0ºC. The annual range of temperature ranges between 11.49ºC and 12.64ºC showing that the existence of high variability of temperature in the study area. The warmest year was in 2013, 22.09 ºC, while the coldest year was in 1990, 8.89 ºC (Annex-5.3).

Generally, the trend of maximum and minimum temperature shows slight increment from year to year in between 1987-2017. As indicated in Figure 4.5, the maximum and minimum annual temperature of the study area has increased by 0.98 ºC and 0.46 ºC in the past three decades respectively. On the other hand, the result showed that the trend of average annual temperature has increased by about 0.72 ºC in the past three decades. Annual maximum/day time temperature is increased faster than the minimum temperature in the study site. The highest minimum temperature increment was observed in the first decades. Whereas the highest maximum temperature increment was took place in the third decade. Therefore, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. But, in the study area factors that affect agricultural production, such as changes in farming practices and yields will decline.

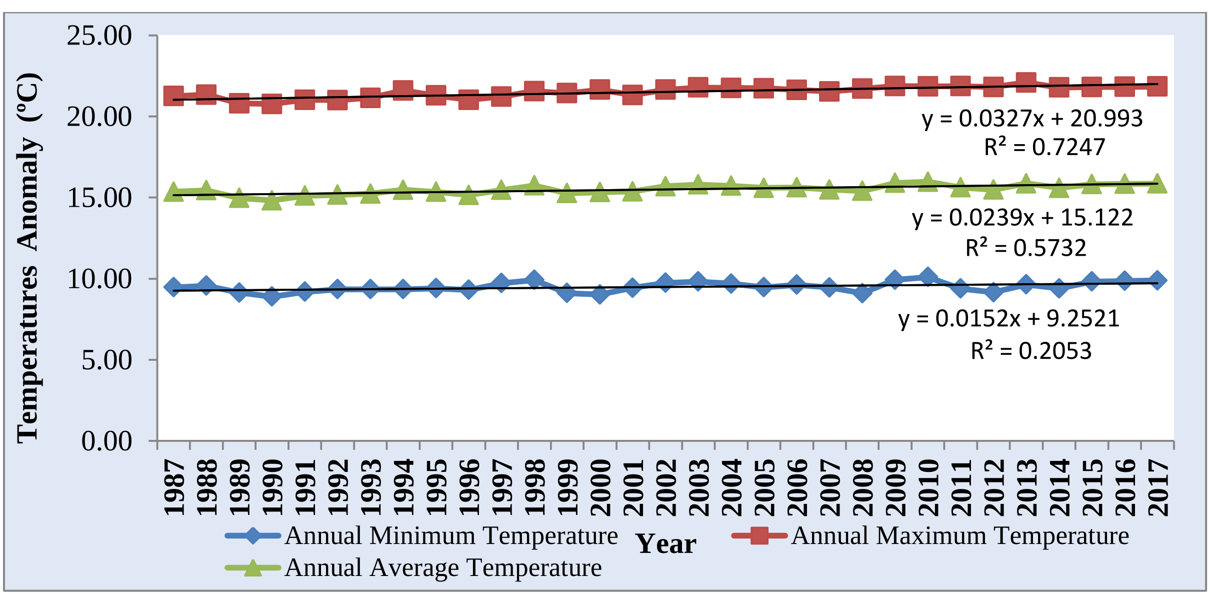

Figure 4.5: Trend of maximum, minimum, and average annual temperature

Source: NMA (2018)

4.2.2. Trends of annual and seasonal rainfall

According to NMA (2015) there are three seasons in Ethiopia; *Belg* (spring), *Kiremt* (summer), and *Bega* (winter). *Belg* (February-May) is the small rainy season in Ethiopia. Much of the northeastern, central southern, eastern and south eastern parts of the country receive considerable amount of rainfall during this season. *Kiremt* (June-September) is the main rainfall season for most parts of the country except for the lowlands of southern and south eastern Ethiopia. *Bega* (October-January) is mostly a dry season for most parts of the country except for southwestern as well as the lowlands of south and southeast Ethiopia.

The annual rainfall of Siyadeberina wayu *woreda* ranges between 735.1 mm as a minimum, and 1187.1mm as a maximum, for the past 30 years. Data analysis result shows annual rainfall has an increasing and decreasing trend in the past three decades. As can be seen in Figure 4.6, the amount of rainfall fluctuated yearly between 1987 and 2017. The annual mean rainfall of the *woreda* is 980.24 mm in the past three decades (Annex-5.4). The inter-annual patterns of rainfall distribution showed that annual amounts of rainfall were below the average in year 1987, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1999, 2000, 2001, 2002, 2005, and 2013.

The trend of Annual, Belg, and Kiremt rainfall of the study area indicated in Figure 4.6. Annual rainfall has increased significantly by 153.73 mm, in small rainy season (Belg) rainfall has decreased by 30.78 mm and insignificant, and in main rainy season (Kiremt) rainfall has increased significantly by 120.96 mm in the past three decades. In the first decade the study area annual rainfall, main rainy season rainfall and small rainy season rainfall shows very high decreased trend. Whereas a significant increased trend of annual rainfall, and main rainy season rainfall took place in the third decade.

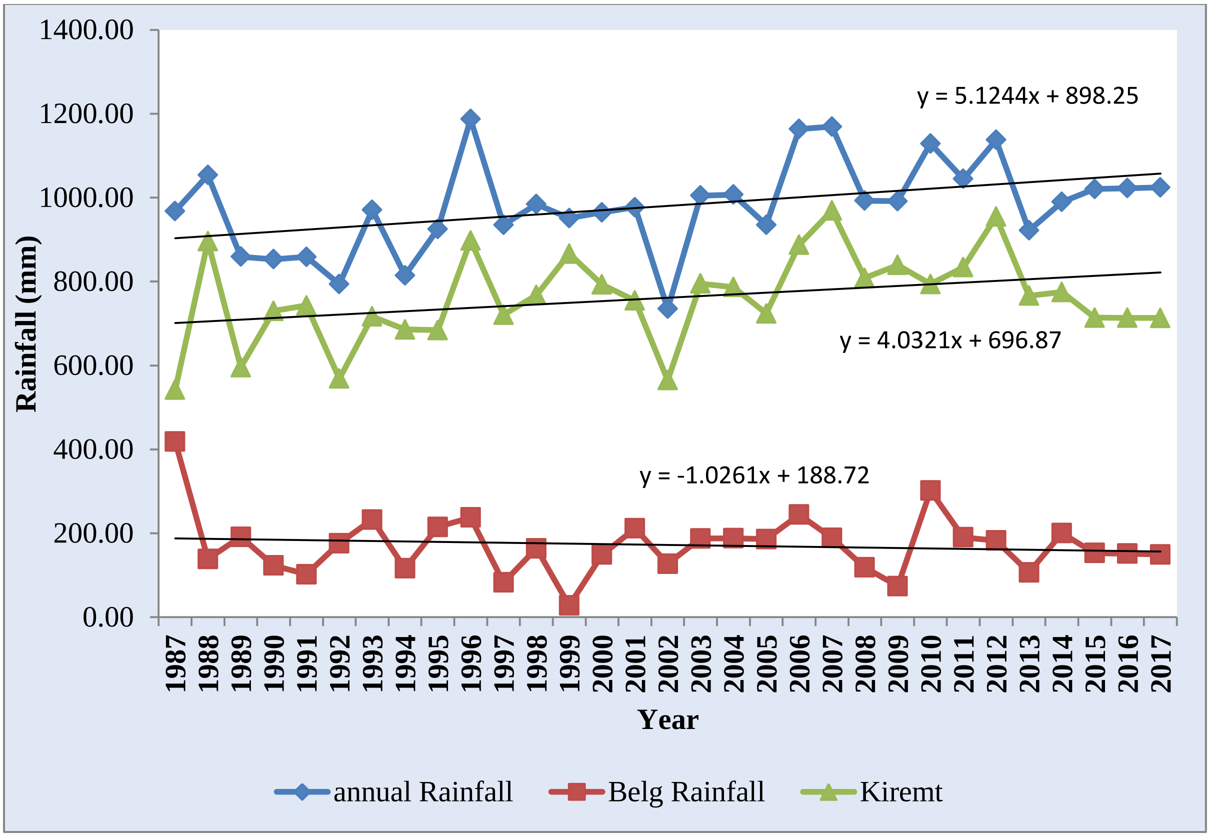

Figure 4.6: Trend of Annual and Seasonal Rainfall

Source: NMA (2018)

4.2.3. Average monthly rainfall and temperature distribution

Based on the three seasons (*Belg*, *Kiremt*, and *Bega*) in the study area the average monthly rainfall and temperature distribution was analyzed. NMA (2018) shows the wettest month is July with an average rainfall of 319.88mm and average temperature 14.5ºC, while the driest month is December with an average rainfall of 5.17 mm and average temperature 14.3ºC. On the other hand during belg season observed the highest average rainfall in the month of April 58.53mm and the highest average temperature observed in the month of May 17.2ºC in the study area.

The long term annual and seasonal rainfall variability shows in Table 4.11. Average mean for annual rainfall, small rainy season (Belg) rainfall, and main rainy season (Kiremt) rainfall was computed as 980.24 mm, 172.30 mm, and 761.38 mm with standard deviation of 108.82, 72.54 and 106.16 respectively. Similarly, the coefficient of variation in annual, belg, and kiremet season rainfall is 11.10%, 42.10%, 13.94% respectively, which means this much amount of rainfall is deviated from the mean (Annex 5.5).

Table 4.11: Annual and seasonal rainfall (mm), standard deviation and coefficient of Variation, (1987–2017).

Rainfall	**Mean**	**Standard Deviation**	**Coefficient of Variation**
Annual	980.24	108.82	11.10
Belg	172.30	72.54	42.10
Kiremt	761.38	106.16	13.94

Source: NMA (2018)

Ethiopian agriculture is mostly rain-fed, whereas inter-annual and seasonal rainfall variability is high and droughts frequent in many parts of the country. Rainfall variability has historically been a major cause of food insecurity and famines in the country (Bewket, 2009). Therefore, changes in rainfall conditions have a direct and immediate impact on the performance of agricultural sector as well as in the country's total GDP (FAO. 2006).

The precipitation concentration index (PCI) was used to calculate rainfall variability at annual scale across different part of the world. To analyze climate variability many scholar use different methods from these methods PCI and using coefficient of variation were highly used by in Ethiopia (Seleshi & Zanke, 2004). The coefficient of variation (CV) can be calculated by dividing the standard deviation to the long term mean precipitation (NMA, 1996). Precipitation was characterized by a typical annual pattern with low rainfall totals during belg and bega seasons and high during kiremt season in the study area.

According to Oliver (1980) the analysis of rainfall variability in the study area shown the precipitation concentration index (PCI) for annual scale is greater than 20 (21.07) which indicated a strong irregularity (highly variable) distribution in annual rainfall. According to NMSA (1996) classified the rainfall variability of an area shown the coefficient of variation in annual rainfall variability is less than 20% (11.10%) which shows less variation. The coefficient of variability in belg season rainfall is greater than 30% (42.10%) which indicated highly variable, and in kiremt season rainfall is less than 20% (13.94%) indicated less variable in the past three decades.

4.2.4. Severity of drought

Drought is a natural local or regional phenomenon, its basic cause being the lack of precipitation over a time period. Drought may be studied from the environmental or the water resources point of view. Environmental droughts can be classified into meteorological, hydrological, and agricultural drought (Wilhite and Glantz, 1985). This study was focused on meteorological drought, which can be expressed by the so-called drought indices.

According to Agnew & Chappel (1999) drought severity assessment method Figure 4.7, shows that the drought severity scales in the study area between the years 1987-2017. Extreme droughts observed in the study area in the year 1992 and 2002 (-1.71 and -2.25 respectively), severe drought appeared in 1994 (-1.52), moderate drought shows in the years 1989, 1990, and 1991 (-1.11, -1.17, and -1.12 respectively). The rest year was not observed drought in the study area.

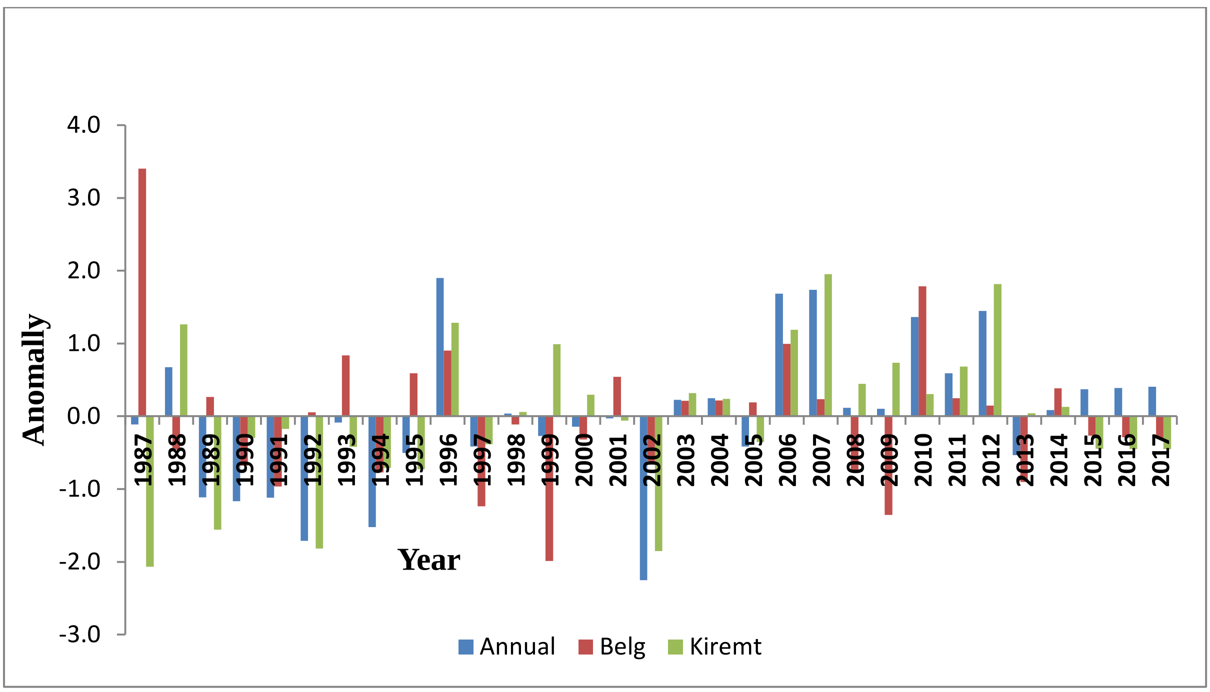

Figure 4.7: Drought severity. Source: NMA (2018)

The above figure indicates wet and dry years, 1987 was an extremely wet year due to occurrence of high rainfall or other phenomena. Extreme drought severity observed in the years 1992 and 2002; severe drought observed in 1994, moderate drought occurred in the years 1989, 1990, and 1991 these shows the periods received below normal rainfall. In this event interrupt food delivery, and resulting spikes in food prices. Drought may threaten pasture and feed supplies, reduces the amount of quality forage available to grazing livestock, changes in crop production and reduce yields. During wet years, high crop production was experienced, with larger numbers of livestock while, dry years experienced low production of crops, reduced number of livestock. Factors, which contributed to reduction in number of livestock during the dry seasons in the study area included lack of pasture and water, selling of livestock at cheap prices to earn money for food and moving livestock to other places in search for good pastures.

4.3. Climate Smart Agricultural Practices in the Study Area

According to Keller (2009) the impacts of climate change were late rain (which means a shorter rainy season), frost (extreme cold weather), droughts and crop pests. The late rain and droughts leads: crop loss, decreased productivity or loss of livestock, water shortage, soil erosion, reduced income from agricultural production, food insecurity/famines, and decreased ability to meet other basic needs. The crop pests lead: reduced soil productivity, reduced livestock feed, and food insecurity. Regarding the impacts of late rain and droughts the following coping strategies were identified: crop diversification, fallowing, using crop residues, water harvesting, and tree planting (Keller, 2009). Figure 4.8, summarizes perception of climate change and severity of the climate problem. The figure indicated that 36% of the respondents reported high severity of the climate problem in the study area, 35% medium, and 29% low severity. The reasons were major climate problems such as late rain and drought, occurrence of crop pests, and frost.

In a similar way, KIIs and FGDs that were made with different targeted individuals and groups confirmed the same results of household survey on climate change/variability. The results was general observable local climate change and severity of the problem specifically weather events are increased temperature and drought; decreased rainfall amount, late in duration, and unpredictability; occurrence of pests and diseases; and unusual coldness. These findings are confirmed with IPCC (2007) study result that climate change and variability became both a global and local real phenomena and manifested with different forms of weather events. The result also sowed climate change adversely impacts on the crop production and affected the food and nutritional security, livelihood and income of smallholder farmers.

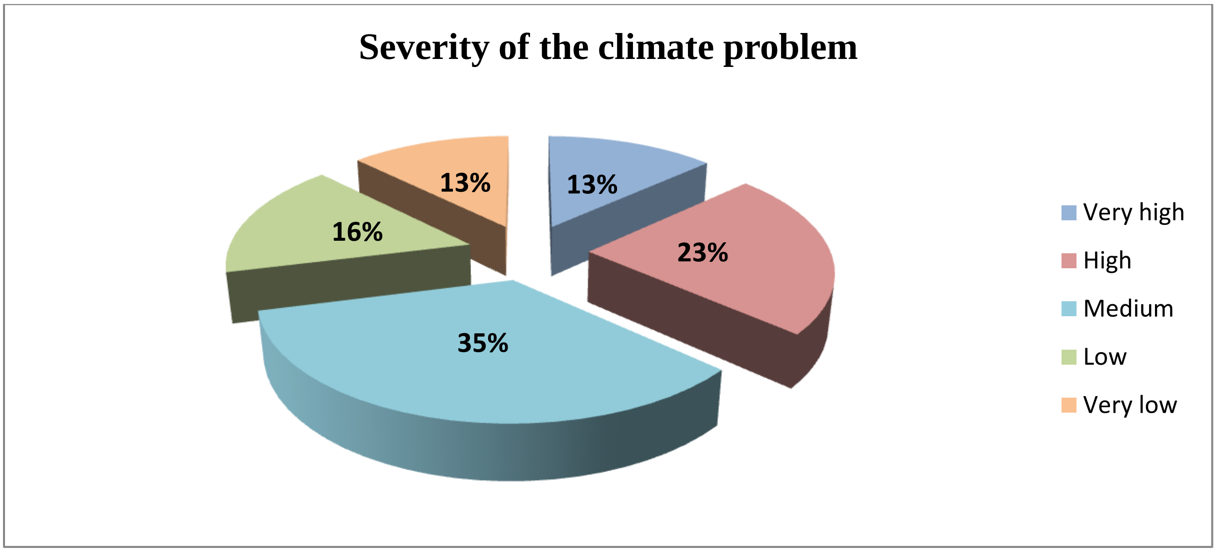

Figure 4.8: Severity of the climate problem (Source: Field survey data, February, 2019)

Data were analyzed using descriptive statistics to identify local climate smart agriculture practices in the study area including mean and percentage. According to Saguye (2017) the following criteria were used to rank the rate of adoption based on the percentage of the respondents in the total sample. Adoption rate greater than 70% = very high, Adoption rate within 60 to 70% = high, Adoption rate within 50 to 59% = fairly high, Adoption rate within 40 to 49% = fairly low Adoption rate below 40% = very low.

According to Branca *et al.* (2013), FAO (2013) and Saguye (2017) the following climate smart agricultural practices were categorized: agronomic practices are (improved seed varieties, crop rotation, intercropping, and cover crop); integrated soil fertility management (organic fertilizer and efficient use of inorganic fertilizer); tillage and residue management (conservation tillage and incorporation of crop residues); water management (irrigation, bunds, terracing, contouring, and water harvesting); integrated pest management (blend of cultural, biological and chemical control); agro-forestry (intercropping crops and trees, live fencing).

Distribution of respondents according to the level of adoption of the selected climate smart agricultural practices was presented in Table 4.12. Practices such as crop rotation or intercropping with cereals and legumes (71.74%); efficient fertilizer application techniques (89.40%); popularization of new crops and improved crop varieties (75.27%); pest resistance, high yielding, and drought and heat tolerant crops (77.45%) were highly adopted. Post-harvest technologies (58.7%) were also fairly adopted while adoption of other components of climate smart agriculture practices (conservation tillage (25.54%), crop residue management (41.03%), mulching (13.04%), compost and manure management (27.72%), water management (8.87%), agro-forestry (32.97%), improved livestock feed and feeding practices (37.32%), early-warning systems and weather information (29.35%), and livelihood diversification (5.71%) were low. Generally farmers' adoption rates of the climate smart agricultural practices in the study area were very low.

Key informants and Focus group reported that feed shortage occurs during the period between February to May and conservation feeding is one of the feeding strategy used to reduce the shortage during this time. Conservation and concentrate feeding is common and adopted practice by most farmers mainly during feed shortage. This finding is in line with CSA (2017) reported that identified livestock feed resources in Ethiopia are mainly obtained from natural and improved pastures, feed conservation (hay making, silage making, and crop residue), forage crops, agro-industrial by-products and non-conventional feeds.

Table 4.12: Adoption of Climate smart agriculture practices in the study area

Category	CSA Practices	Kebele						Total		%	
		Ejersa		Kombolcha		Wele					
		Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted
Conservation agriculture	Reduced tillage	0	68	61	94	33	112	94	274	25.54	74.46
	Crop residue mgmt.	10	58	71	84	70	75	151	217	41.03	58.97
	Mulching	1	67	10	145	37	108	48	320	13.04	86.96
	Crop rotation	59	9	98	57	107	38	264	104	71.74	28.26
Integrated soil fertility management	Composting	11	57	67	88	24	121	102	266	27.72	72.28
	Fertilizer application techniques	61	7	136	19	132	13	329	39	89.40	10.60
Small scale irrigation	Year-round cropping	0	68	26	129	13	132	39	329	10.60	89.40
	Efficient water utilization	1	67	11	144	12	133	24	344	6.52	93.48

Category	CSA Practices	Kebele						Total		%	
		Ejersa		Kombolcha		Wele					
		Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted	Adopted	Non adopted
Agro forestry	Tree-based conservation agriculture	1	67	38	117	22	123	61	307	16.58	83.42
	Improved practice	10	58	58	97	94	51	162	206	44.02	55.98
	natural regeneration	2	66	61	94	78	67	141	227	38.32	61.68
Crop diversification	Popularization of improved crop varieties	58	10	127	28	92	53	277	91	75.27	24.73
	Pest resistance, high yielding, and drought & heat tolerant crops	63	5	107	48	115	30	285	83	77.45	22.55
Improved livestock feed	Reduced open grazing	38	30	71	84	39	106	148	220	40.22	59.78
	Forage development	15	53	41	114	31	114	87	281	23.64	76.36
	Feed improvement	23	45	69	86	85	60	177	191	48.10	51.90
	breed improvement & diversification	41	27	90	65	101	44	232	136	63.04	36.96
Water harvesting		0	68	25	130	10	135	35	333	9.51	90.49
Early-warning systems & improved weather information		8	60	51	104	49	96	108	260	29.35	70.65
Livelihoods diversification		1	67	14	141	6	139	21	347	5.71	94.29
Post-harvest technologies		24	44	81	74	111	34	216	152	58.70	41.30

Source: Field survey data (February, 2019)

Therefore, based on this analysis the local CSA practices were identified such as crop rotation; fertilizer application; popularization of new technology crop varieties; using pest resistance, high yielding, tolerant to drought & short season varieties; and post- harvest technologies are highly adopted in the study area.

In a similar way, Aweke (2017) finds adoption levels of some CSA practices and technologies, such as conservation agriculture and agroforestry, among smallholder farmers remain low. FAO (2016) also indicated in the broader Ethiopian context, CSA practices and technologies are being implemented within the framework of integrated watershed management, which incorporates a broad range of practices in crop and livestock production including agroforestry, crop rotation and intercropping, soil and water conservation. In terms of adoption, most of the CSA practices and technologies identified have low to medium on-farm adoption rates, despite their potential benefits to adaptation, productivity increase and mitigation efforts.

4.4. Determinants of Climate Smart Agricultural Practices

Binary logistic regression model describes the relationship between a dichotomous response variable (adoption of climate smart agriculture practices) and a set of explanatory variables that aimed to reduce the adverse impact of climate change and variability. The logistic model is special case of generalized linear model where the assumptions of normality and constant variance of residuals are not satisfied. The problem of multicollinearity among the explanatory variables was tested using variance inflection factor and contingency coefficient for continuous and dummy explanatory variables respectively. There was no multicollinearity problem for categorical and dummy variables and in this study multicollinearity detected in continuous explanatory variables.

As indicated in Table 4.13 multicollinearity was observed between family size and age of the household head, farm size and family size, experience in agriculture and farm size are predicted that there is a positive relationship among them and significantly correlated at 0.01 level and they are very important variables in influencing the adoption of climate smart agriculture practices. The market distance from farm/home and family size also significantly correlated at the 0.05 significance level.

Table 4.13: Correlation test result for continuous explanatory variables

	AGE	HHSZ	LAND	FEXPER	DISMKT
AGE	1				
HHSZ	.355**	1			
LAND	.248**	.216**	1		
FEXPER	.947**	.370**	.222**	1	
DISMKT	-.096	-.115*	-.012	-.091	1
Sig. (2-tailed)	.066	.027	.825	.083	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Sample size (n) = 368

Source: Field survey data (February, 2019)

The individual coefficients and standard errors produced identical to those that would be produced by multiple linear regressions estimating each equation separately while multivariate regression being a joint estimator. The findings of the binary logistic regression model indicated that significance and impact of each explanatory variable on the response variable. A model was employed to identify the major factors that influence the adoption of climate smart agriculture practices.

Oates (2015) stated to observe the tests of individual variables in this model, the maximum likelihood, estimates (coefficients), the Wald statistics, confidence intervals and odds ratios (Exp(B)) were presented. The odds ratio estimates tells us the change in “odds” of being in one of the categories of the dependent variable for every unit increase of any given variable in the model. A value of one for the odds ratio means that there is no change in odds as the variable increased. A value of less than one for the odds ratio means that for every unit increase of a given variable the odds of adoption of CSA decreases. A value of more than one means that for every unit increase of a given variable the odds of adoption of CSA practices increases. In addition to the odds ratios, a 95% confidence interval for each of the odds ratio estimates was calculated. The Cox and Snell R Square and the Nagelkerke R Square are referred to as “pseudo R-squared statistics” as reported by Hosmer and

Lemeshow (2001). Each of the logistic regression models passed the goodness of fit tests recommended by Pallant (2007) and Hosmer and Lemeshow (2001).

The results of binary logistic regression model as shown in Table 4.14 four variables (household size, farming system, farm income source and off-farm income) are statistically significant at (p= 0.012, 0.000, 0.001, and 0.048 level) and influencing the adoption of conservation agriculture respectively. A farm income source is a factor that adversely affects adoption of conservation agriculture and the value of odds ratio is less than one (0.336) for every unit increase of a given variable. While the remaining variables have positive relationship, value of odds ratio is more than one and significantly enhance the adoption of conservation agriculture. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.14: Factors influencing adoption of conservation agriculture

Dependent Variable: Adoption of Conservation Agriculture							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B)	
						Lower	Upper
Sex of the household head	-.289	.443	.425	.514	.749	.315	1.785
Age of the household head	-.014	.013	1.128	.288	.986	.961	1.012
Household size	.185	.073	6.353	.012*	1.203	1.042	1.388
Farm size	-.169	.183	.845	.358	.845	.590	1.210
Farming system	2.527	.408	38.314	.000***	12.517	5.623	27.863
Access to Irrigation	-.741	.744	.993	.319	.477	.111	2.048
Farm Income sources	-1.089	.315	11.960	.001***	.336	.181	.624
Off-farm Income	.871	.440	3.913	.048**	2.390	1.008	5.667
Access to extension service	-.645	.789	.668	.414	.525	.112	2.463
Distance to market	-.045	.038	1.373	.241	.956	.887	1.031
Access to weather information	-.249	.302	.681	.409	.779	.431	1.409
Constant	1.297	1.104	1.382	.240	3.660		

Number of observation = 368

Prob > chi2 = 0.000 , Chi-square = 103.594, df = 11

Cox & Snell R^2 = 0.245 , Nagelkerke R^2 = 0.331, -2 Log likelihood = 393.166

Hosmer-Lemeshow Test - Chi-square = 26.971, df = 8, p = 0.001

*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

As indicated in Table 4.15 two variables (farm income source and off-farm income) are statistically significant variables at (p= 0.028, and 0.034 level) respectively influencing the adoption of integrated soil fertility management. A farm income source is factors that adversely affect integrated soil fertility management, the value of odds is less than one (0.523) for every unit increase of a given variable while the off-farm income has positive relationship, value of odds is more than one and significantly increase the adoption. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.15: Factors influencing adoption of integrated soil fertility management

Dependent Variable: Adoption of Integrated Soil Fertility Management							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B)	
						Lower	Upper
Age of the household head	-.037	.039	.907	.341	.964	.893	1.040
Household size	-.050	.068	.541	.462	.951	.833	1.087
Farm size	.102	.174	.341	.559	1.107	.787	1.556
Farming experience	.040	.042	.928	.335	1.041	.959	1.131
Farming system	-.531	.350	2.298	.130	.588	.296	1.168
Farm income sources	-.649	.296	4.809	.028**	.523	.293	.933
Off-farm income	.857	.405	4.471	.034**	2.356	1.065	5.212
Distance to market	-.025	.034	.512	.474	.976	.912	1.044
Constant	.455	.889	.261	.609	1.575		

Number of observation = 368

Prob > chi2 = 0.089, Chi-square = 13.742, df = 8

Cox & Snell R^2 = 0.037, Nagelkerke R^2 = 0.053, -2 Log likelihood = 420.693

Hosmer-Lemeshow Test - Chi-square = 16.081, df = 8, p = 0.041

*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

Table 4.16 showed that three variables (farm size, access to irrigation, and distance to market) are statistically significant at (p= 0.015, 0.000, and 0.000 level) respectively affecting the adoption of small scale irrigation. A farm size is a factor that adversely affects adoption of small scale irrigation, the value of odds is less than one (0.498) for every unit increase of a given variable, while access to irrigation and distance to market variables have positive relationship, value of odds ratio is more than one and significantly enhance the adoption of small scale irrigation. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.16: Factors influencing adoption of small scale irrigation

Dependent Variable: Adoption of Small scale Irrigation							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B)	
						Lower	Upper
Sex of the household head	1.031	.795	1.684	.194	2.804	.591	13.310
Farm size	-.698	.285	5.974	.015*	.498	.284	.871
Access to irrigation	4.970	1.122	19.620	.000***	144.060	15.97	1299.1
Farm income sources	-.815	.446	3.335	.068	.443	.185	1.062
Access to agricultural credit	-.267	.383	.488	.485	.765	.361	1.621
Distance to market	.185	.045	17.106	.000***	1.204	1.102	1.314
Acc. to weather information	-.535	.451	1.411	.235	.585	.242	1.416
Constant	-2.191	.961	5.201	.023	.112		

Number of observation = 368

Prob > chi2 = 0.000, Chi-square = 78.388, df = 7

Cox & Snell R^2 = 0.192, Nagelkerke R^2 = 0.362, -2 Log likelihood = 198.915

Hosmer-Lemeshow Test - Chi-square = 13.968, df = 8, p = 0.083

*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

The data analysis result in Table 4.17 indicates six variables (household size, farming system, farm income source, access to extension service, distance to market and access to weather information) are statistically significant at (p= 0.033, 0.001, 0.028, 0.002, 0.000, and 0.005 level) respectively influencing the adoption of agro-forestry. Farming system, farm income source, access to extension service, and distance to market are factors that adversely affect adoption of agro-forestry, the value of odds is less than one (0.338, 0.526, 0.046, and 0.861) respectively. Whereas household size and access to weather information variables have positive relationship, value of odds ratio is more than one and significantly enhance the adoption of agro-forestry. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.17: Factors influencing adoption of agro-forestry

Dependent Variable: Adoption of Agro-forestry							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B) Lower	Upper
Sex of the household head	-.595	.408	2.122	.145	.552	.248	1.228
Household size	.137	.064	4.551	.033**	1.147	1.011	1.300
Farming system	-1.084	.334	10.526	.001***	.338	.176	.651
Farm income sources	-.642	.292	4.840	.028**	.526	.297	.932
Off-farm income	-.826	.484	2.908	.088	.438	.169	1.131
Access to extension service	-3.070	1.008	9.270	.002**	.046	.006	.335
Distance to market	-.150	.037	16.035	.000***	.861	.800	.926
Acc. to weather information	.849	.303	7.840	.005***	2.338	1.290	4.236
Constant	3.235	1.166	7.700	.006	25.411		

Number of observation = 368
Prob > chi2 = 0.000, Chi-square = 49.458, df = 8
Cox & Snell R^2 = 0.126, Nagelkerke R^2 = 0.173, -2 Log likelihood = 430.903
Hosmer-Lemeshow Test - Chi-square = 31.685, df = 8, p = 0.000
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

The result shown in Table 4.18 access to agricultural credit is statistically significant at (p= 0.011) level. This variable has positive relationship between the adoption of crop diversification and the value of odds ratio is more than one (2.717) and significantly increases the adoption. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.18: Factors influencing adoption of crop diversification

Dependent Variable: Adoption of Crop Diversification							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B) Lower	Upper
Age of the household head	-.054	.052	1.072	.300	.948	.856	1.049
Farming experience	.051	.057	.827	.363	1.053	.942	1.176
Farming system	.516	.523	.973	.324	1.675	.601	4.672
Off-farm income	-1.055	.552	3.648	.056	.348	.118	1.028
Access to agricultural credit	.999	.391	6.545	.011**	2.717	1.263	5.842
Distance to market	.096	.063	2.276	.131	1.100	.972	1.246
Constant	2.490	1.239	4.040	.044	12.062		

Number of observation = 368
Prob > chi2 = 0.051, Chi-square = 12.530, df = 6
Cox & Snell R^2 = 0.033, Nagelkerke R^2 = 0.074, -2 Log likelihood = 209.582
Hosmer-Lemeshow Test - Chi-square = 23.885, df = 8, p = 0.002
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

Table 4.19 presents four variables (farm size, farming system, off-farm income, access to agricultural credit, and access to extension services) are statistically significant at (p= 0.035, 0.000, 0.020, and 0.021 level) respectively. Off-farm income and access to extension service are factors that adversely affect the adoption of improved livestock feed, the value of odds ratio are less than one (0.051 and 0.048) respectively for every unit increase of a given variable. While farm size and access to agricultural credit variables have positive relationship, value of odds ratios are more than one (1.440 and 1.733) and significantly enhance the adoption of improved livestock feed. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.19: Factors influencing adoption of improved livestock feed

Dependent Variable: Adoption of Improved Livestock Feed							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B)	
						Lower	Upper
Sex of the household head	-.470	.414	1.294	.255	.625	.278	1.405
Age of the household head	.065	.039	2.785	.095	1.067	.989	1.152
Farm size	.364	.173	4.462	.035**	1.440	1.027	2.019
Farming experience	-.079	.042	3.423	.064	.924	.851	1.005
Access to irrigation	-.661	.591	1.253	.263	.516	.162	1.643
Farm income sources	.552	.297	3.455	.063	1.737	.970	3.108
Off-farm income	-2.983	.639	21.800	.000***	.051	.014	.177
Access to agricultural credit	.550	.237	5.391	.020**	1.733	1.090	2.757
Access to extension service	-3.035	1.313	5.342	.021**	.048	.004	.630
Acc. to weather information	.341	.275	1.537	.215	1.406	.820	2.412
Constant	1.427	1.615	.781	.377	4.168		

Number of observation = 368
Prob > chi2 = 0.000, Chi-square = 58.316, df = 10
Cox & Snell R^2 = 0.147, Nagelkerke R^2 = 0.198, -2 Log likelihood = 436.858
Hosmer-Lemeshow Test - Chi-square = 8.153, df = 8, p = 0.419
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

As can be seen in Table 4.20 access to irrigation and access to extension service variables are statistically significant at (p= 0.002 and 0.005 level) respectively. There was a negative relationship between adoption of water harvesting with access to extension service, the value of odds ratio is less than one (0.061) for every unit increase of a given variable. While access to irrigation has a positive relationship, the values of odds ratio is more than one

(43.745) and significantly enhance the adoption of water harvesting. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.20: Factors influencing adoption of water harvesting

Dependent Variable: Adoption of Water Harvesting							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B) Lower	Upper
Sex of the household head	.403	.803	.252	.616	1.497	.310	7.228
Age of the household head	-.011	.062	.034	.854	.989	.875	1.117
Household size	.173	.118	2.155	.142	1.189	.944	1.498
Farm size	-.409	.299	1.870	.171	.664	.370	1.194
Farming experience	-.015	.068	.047	.828	.985	.863	1.125
Farming system	-20.72	4049.99	.000	.996	.000	.000	.
Access to irrigation	3.778	1.232	9.408	.002**	43.745	3.912	489.20
Farm income sources	-.524	.486	1.163	.281	.592	.228	1.535
Off-farm income	-19.77	6281.56	.000	.997	.000	.000	.
Access to agricultural credit	.177	.426	.172	.678	1.193	.518	2.750
Access to extension service	-2.796	.996	7.881	.005***	.061	.009	.430
Distance to market	-.052	.057	.854	.356	.949	.849	1.061
Acc. to weather information	-.161	.483	.110	.740	.852	.330	2.197
Constant	1.654	1.921	.741	.389	5.229		

Number of observation = 368
Prob > chi2 = 0.000, Chi-square = 53.372, df = 13
Cox & Snell R^2 = 0.135, Nagelkerke R^2 = 0.289, -2 Log likelihood = 177.880
Hosmer-Lemeshow Test - Chi-square = 2.149, df = 8, p = 0.976
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

As shown in Table 4.21 four variables (access to irrigation, access to extension service, distance to market and access to weather information) are statistically significant at (p= 0.020, 0.043, 0.001, and 0.001 level) and affecting the adoption of early warning system respectively. Access to extension service and distance to market are factors that adversely affect adoption of early warning system and the value of odds ratio is less than one (0.202 and 0.874) respectively, for every unit increase of a given variable. While access to irrigation and access to weather information variables have a positive relationship, value of odds ratio is more than one (4.283 and 3.042) and significantly increase the adoption of early warning system. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.21: Factors influencing adoption of early warning system

Dependent Variable: Adoption of Early warning system							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B) Lower	Upper
Sex of the household head	-.379	.440	.742	.389	.685	.289	1.621
Age of the household head	-.045	.041	1.206	.272	.956	.882	1.036
Household size	.047	.070	.452	.501	1.048	.914	1.201
Farm size	-.258	.180	2.058	.151	.772	.543	1.099
Farming experience	.038	.044	.750	.386	1.039	.953	1.134
Farming system	-.268	.348	.593	.441	.765	.387	1.513
Access to irrigation	1.455	.626	5.400	.020**	4.283	1.256	14.60
Farm income sources	.429	.330	1.690	.194	1.536	.804	2.934
Off-farm income	-.277	.482	.332	.564	.758	.295	1.947
Access to agricultural credit	-.489	.251	3.801	.051	.613	.375	1.003
Access to extension service	-1.601	.793	4.077	.043**	.202	.043	.954
Distance to market	-.134	.039	11.57	.001***	.874	.809	.945
Acc. to weather information	1.112	.337	10.89	.001***	3.042	1.571	5.887
Constant	2.105	1.32	2.534	.111	8.207		

Number of observation = 368
Prob > chi2 = 0.000, Chi-square = 37.533, df = 13
Cox & Snell R^2 = 0.097, Nagelkerke R^2 = 0.138, -2 Log likelihood = 407.921
Hosmer-Lemeshow Test - Chi-square = 20.761, df = 8, p = 0.008
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

The survey result in the Table 4.22 indicates four variables (farming system, off-farm income, access to extension service, distance to market and access to weather information) are statistically significant at (p= 0.000, 0.000, 0.005, 0.034 and 0.000 level) and affecting the adoption of post-harvest technologies respectively. Off-farm income, Access to extension service and distance to market are factors that adversely affect adoption of post-harvest technologies and the value of odds ratio is less than one (0.084, 0.034 and 0.932) respectively, for every unit increase of a given variable the adoption is decreased. While farming system and access to weather information variables have positive relationship, value of odds ratio is more than one (12.89 and 4.474) and increase the adoption of post-harvest technologies. The result also indicated the insignificant variables odds ratio and the value of 1.000 included between the lower and upper confidence interval.

Table 4.22: Factors influencing adoption of post-harvest technologies

Dependent Variable: Adoption of Post-harvest technologies							
Independent Variables	B	S.E.	Wald	Sig.	Exp (B)	95% C.I. for EXP(B) Lower	Upper
Sex of the household head	-.317	.433	.537	.464	.728	.312	1.701
Household size	-.104	.073	2.013	.156	.901	.781	1.040
Farming experience	-.026	.014	3.501	.061	.974	.947	1.001
Farming system	2.556	.476	28.87	.000***	12.89	5.073	32.75
Access to irrigation	-.890	.756	1.387	.239	.411	.093	1.806
Farm income sources	.295	.323	.833	.361	1.343	.713	2.529
Off-farm income	-2.477	.588	17.75	.000***	.084	.027	.266
Access to agricultural credit	.358	.249	2.054	.152	1.430	.877	2.332
Access to extension service	-3.380	1.190	8.062	.005**	.034	.003	.351
Distance to market	-.070	.033	4.515	.034**	.932	.874	.995
Acc. to weather information	1.498	.325	21.24	.000***	4.474	2.366	8.459
Constant	3.833	1.357	7.980	.005	46.21		

Number of observation = 368
Prob > chi2 = 0.000, Chi-square = 99.906, df = 11
Cox & Snell R^2 = 0.238, Nagelkerke R^2 = 0.320, -2 Log likelihood = 399.063
Hosmer-Lemeshow Test - Chi-square = 21.203, df = 8, p = 0.007
*Significant at 10% , ** at 5%, *** at 1% level

Source: Field survey data (February, 2019)

In summary, the major factors that influence the adoption of climate smart agriculture practices were identified in this study. The results showed that there were significant differences with regards to explanatory variables such as household size, farming system, farm income source, off-farm income, farm size, access to irrigated farm, distance to market, access to extension service, access to weather information, and access to agricultural credit. Factors such as household size, access to irrigated farm, distance to market, access to weather information, and access to agricultural credit service have positive relationship and farming system, farm income source, off-farm income, farm size, and access to extension service have negative relationship and significant effect on adoption of climate smart agriculture practices.

Therefore, crop & livestock production would have higher productivity that factors of farming system, farm size, access to irrigated farm, access to extension service, distance to market, and access to weather information are more likely to adopt climate smart agriculture practices and its implication to food security in the study area.

CSA implications to food security

There is a consensus that climate change and agriculture have cause and effect relationships. Increases in the frequency and intensity of extreme events such as drought, rainfall intensity, hotness, and coldness have the potential to adversely affect agricultural production and the food system, worsen food insecurity and deepen poverty. Agricultural activities such as application of chemical fertilizer, crop production and ruminant animals, land use, land cover change, and deforestation contribute significant amount of greenhouse gases. Hence, adjustment of the traditional way of farming practices to absorb these shocks and minimize emission of greenhouse gases is not an option (IPCC, 2014). Therefore, the promotion and adoption of context specific socioeconomic and environmental friendly practices have paramount importance to increase production and ensure food security. In turn this could help to build the resilience of the farming community. It is with this premise that CSA has introduced to increase agricultural production and productivity in sustainability. CSA practices can be adopted in a wide range of different combinations, and this has implication on household's food security status.

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. CSA pathways result in higher resilience and lower risks to food security, whereas business as usual leads to higher risks of food security and lower resilience of food and agricultural systems (McCarthy et al., 2011). 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. Climate change alters agricultural production and food systems, and thus the approach to transforming agricultural systems to support global food security and poverty reduction (Porter, J.R. et al., 2014).

The adoption of CSA could help to positively affect the all dimensions of food security and hence food system. Food security implications of changes in agricultural production patterns, impacts on the production of food will affect food supply, and higher yields. Impacts on all forms of agricultural production will affect livelihoods and access to food. Producer groups that are less able to deal with climate change, such as the rural poor, risk having their safety and welfare compromised. Other food system processes, such as food processing, distribution, acquisition, preparation and consumption, are important for food security as food and agricultural production. The role of agricultural production in food security receives more emphasis than other aspects. The Green Revolution of the 1960s increased the total amount of food produced by applying technologies to improve yields per hectare and by expanding the area under production. This approach increased the availability of food globally both total agricultural production and per capita food availability. Food availability is concerned with the production and supply of crops. Food accessibility focuses on economic and physical access to food relates to the issue of affordability. Food utilization is also the importance of non-food inputs. It takes into consideration the quality of food people to eat and its nutritional value. It also encompasses the process of preparing the food, distribution, health-care, water supply and sanitation conditions. Stability increases supply of sufficient food at all times.

The identified local CSA practices crop rotation; fertilizer application; popularization of new technology crop varieties; pest resistance, high yielding, tolerant to drought & short season varieties; and post- harvest technologies are highly adopted in the study area. Thus, these practices are a means to reduce the agricultural sector sensitive to climate variability and climate change and improve food security components like food availability in broad-spectrum; food accessibility in obtaining households' access to food connected mainly to national food production and allocated through markets and non-market distribution mechanisms; utilization of food and includes the existence of suitable food processing, proper storage practices, and sufficient knowledge application are implies to food security.

Farming communities vary in their asset background such as human capital, natural capital, physical capital, financial capital, information capital. These are determinant factors to CSA adoption and practices. Accordingly, in this empirical study we identified that household size, farming system, farm income source, off-farm income, farm size, access to irrigated farm, distance to market, access to extension service, access to weather information, and access to agricultural credit are determinant factor to CSA adoptions and more responsibility for food security.

Chapter Five

5. Conclusion and Recommendations

5.1. Conclusion

The study examined the extent of farmers' adoption of climate smart agricultural practices as baseline for intervention on climate mitigation measures. The results indicate that a large proportion of respondents were aware of most of the practices, but adoption of most of the practices examined was very low. Local CSA practices such as crop rotation or intercropping with cereals and legumes; efficient fertilizer application techniques; popularization of new crops and improved crop varieties; pest resistance, high yielding, and drought tolerant crops were highly adopted. Post-harvest technologies were also fairly adopted while adoption of other components of CSA practices like minimum tillage; crop residue management; mulching; compost and manure management; water management; agro-forestry; improved livestock feed and feeding practices; early-warning systems; and livelihood diversification were very low and non-adopted.

The major factors influencing the adoption of climate smart agricultural practices were identified and significant differences with regards to explanatory variables such as household size, farming system, farm income source, off-farm income, farm size, access to irrigated farm, distance to market, access to extension service, access to weather information, and access to agricultural credit. Crop and livestock production would have higher productivity that factors of farming system, farm size, access to irrigated farm, access to extension service, distance to market, and access to weather information are more likely to adopt and its implication to food security in the study area.

Most of the people perceive long-term variability in trend of rainfall and temperature. The study showed that both maximum and minimum temperature increased and rainfall had an increasing- decreasing trend during the last three decades. Communities of the study area have been facing challenges due to climate variability impacts like drought, pest and disease, and floods are decreasing agricultural productivity. The information from key informants and focus group discussions intensified the same findings of survey respondents.

5.2. Recommendations

Sensitization campaign on reality of climate change and the need to adopt climate smart agriculture practices towards reduction of adverse effect of climate change should be intensified. Disseminate extensively accurate information on CSA practices to cover a larger proportion of smallholder farmers in the study area.

CSA needs to be mainstreamed into core government strategies, guidelines, manuals and annual action plans. In this regard the experience of the SLM program is a good lesson for integrating CSA technologies into project and program implementation manuals. The government should be given priority to CSA practices that bring productivity gains, enhance resilience and reduce emissions.

Farmers should be encouraged to join farmer social groups, which would expose them to agricultural innovations. Also, the farmers should be well educated and enlightened by extension services on the benefits of CSA practices in agricultural production, which are reducing the negative impact of climate change on their farming activities.

Research, Policy and supportive programs should focus on adoption of climate smart agriculture practices especially those ones that were not highly adopted by farmers and strengthen and encourage adoption of the priority climate smart agriculture practices.

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Annexes

Annex 1: Questionnaire for household survey

Dear respondent,

My name is Tekeste Kifle. 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 Practices, Adoption, Productivity and Its Implication to Food Security' in Siyadebrina Wayu *Woreda*, North Shewa Ethiopia. The prime objective of the thesis is to identify local climate-smart agricultural practices & adoption, determine trends of climate variability, and productivity of agricultural production in the selected *kebele*. 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 questionnaire will take about an hour of your time to respond to the questions.

Thank you in advance for your cooperation.

QUESTIONNAIRE FOR HOUSEHOLD SURVEY

PART – I GENERAL INFORMATION

Date of interview (Date/Month/Year):---------------------------

Name of interviewer: ---

Region: --

Woreda: ---

Kebele: --

Agro ecology: 1. Dega 2. Weynadega 3. Kolla

PART – II DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENT

1. Sex of the household head: 1. male 2. Female
2. Age of the household head: -------------------------- years
3. Marital status of the HH head: 1. Single 2. Married 3. Divorced4. Widowed 5. Polygamous
4. Family size: Male ---------- Female ---------- Total ------------
5. Religion : 1.Orthodox Christian 2.Muslim 3.Protestant 4.Catholic
6. Educational level of the household: 1. Unable to read and write (Illiterate)
    2. First cycle primary school (Grade 1-4) 3. Second cycle primary school (Grade 5-8)
    4. High school (Grades 9 -10) 5. Preparatory (Grade 11-12) 6. TVET and above

PART – III SOCIO-ECONOMIC FACTORS

7. Total farm size of the household ----------------------------------- hectares
8. The slope of the farm land 1. Plain 2. Hilly 3. Steep
9. The level of fertility of the farm land:
    1. Fertile 2. Moderately fertile 3. Less fertile 4. Infertile
10. Experience in agriculture -- years
11. Does the household possess an irrigated farm? 1. Yes 2. No
12. If yes for the above question, what is the size of the irrigated land? ---------- Ha./ timad
13. What crops are irrigated? ---
14. What is your water source for irrigation? --
15. Household crops production and utilization statistics in 2010/11 cropping season

No	Crop type	Land size in Ha.	Amount in Quintals					
			Production in 2010/11	Quantity Sold	Reserved for seed	For consumption	Post-harvest loss	Obtain through PSNP
1	Wheat							
2	Teff							
3	Barely							
4	Maize							
5	Sorghum							
6	Pulses							
7	Oilseeds							
8	vegetables							
9	Others							

16. Livestock of the household statistics:

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

17. Which farming systems are you carryout for living?

1. Only crop production
2. Livestock rearing
3. Mixed farming (crop production & livestock rearing)

18. Household annual income statistics

Income sources	Income in birr/year/household	Remark
Crop sale		
Livestock sale		
Livestock product sale		
Meat		
Butter		
Milk		
Eggs		
Off farm		
Remittance		
PSNP		
Other		

19. 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	Planting of trees		
8	Using irrigation water		
9	Using chemical fertilizer		
10	Using improved seed		
11	Using BBM technology		

20. How much fertilizers you used per hectare during last crop year?

DAP -------- (Qt.) UREA-------- (Qt.) Total ----------- (Qt.)

21. How much improved seed you used during last crop year?....................... (Kg./Ha)

22. Do your family have any sources of off-farm income? 1. Yes 2. No

23. If yes, in which off-farm activities engage your family to earn income.

No	Activities	Amount gained per year
1	Firewood sale	
2	Charcoal sale	
3	Remittance	
4	Others	

24. Expenditure of farm inputs

Type of farm inputs	Used input last year?	Bought or free?	Amount bought (Quintal)	Unit Price (Birr)	If unit price is not known, total cost?
Fertilizer (Urea, NPS, NPSB etc…)					
Seeds					
Herbicides (2-4-D, Tilt, Palas etc….)					
Pesticides for crops (specify)					
Pesticides for livestock (specify)					
Livestock feed					

25. What are your sources of income?

1. Crop sale 2. Livestock sale 3. Crop & Livestock 4. Crop, livestock, & Off-farm

26. How did you judge the trend of crop productivity in your life time?

1. Increased 2. Decreased 3. No change.

PART – IV INSTITUTIONAL FACTORS

27. Do any members of the household have access to credit service in the last 12 months?

1. Yes 2. No

28. If YES, what was the main purpose of the loan?

1. Purchase farm inputs (e.g. seeds, fertilizers) 2. Buy livestock 3. Buy land
4. Construction of farm structures 5. Buy machinery and equipment
6. Payment of labor costs 7. Other (specify) _____________

29. Do you have contact with agricultural extension agents? 1.Yes 2.No

30. If yes for the above question, how many times do you usually meet per cropping year with extension agents? ----------------------------

31. How far is the nearest market from your farm? --------------- Kilo meter

32. Do you have a regular access to weather information 1. Yes 2. No

33. Do you usually participate farmers field day? 1. Yes 2. No

PART – V ADOPTION OF CLIMATE SMART AGRICULTURE PRACTICES

34. What are the main challenges do you face in your farming related to climate variability?..

35. How do you cope with such challenges?...

36. How do you rate the severity of the climate problem?

    1. Very high 2. High 3. Medium 4. Low 5. Very low

37. 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	
7	High temperature	
8	Very cold temperature (wurch)	

38. Are you aware of climate smart agriculture? 1. Yes 2. No

39. Did you or any household member have had information/training on how to use climate smart agriculture? 1. Yes 2. No

40. Are you adopting the following climate smart agriculture practice in your agricultural activities?

No	Climate	Yes/ No
1	Conservation Agriculture- ▪ Reduced tillage ▪ Crop residue management ▪ Mulching ▪ Crop rotation/intercropping with cereals and legumes	
2	Integrated soil fertility management ▪ Compost and manure management, including green manure ▪ Efficient fertilizer application techniques (time, method, amount)	
3	Small scale irrigation- ▪ Year-round cropping ▪ Efficient water utilization	
4	Agro-forestry- ▪ Tree-based conservation agriculture ▪ Practiced both traditionally and as improved practice ▪ Farmer-managed natural regeneration	
5	Crop diversification - Improved seed ▪ Popularization of new crops and crop varieties ▪ Pest resistance, high yielding, and drought tolerant crops	
6	Improved livestock feed and feeding practices – ▪ Reduced open grazing/zero grazing ▪ Forage development and rangeland management ▪ Feed improvement ▪ Livestock breed improvement and diversification	
7	Water harvesting	
8	Early-warning systems and improved weather information	
9	Livelihoods diversification (apiculture, aquaculture)	
10	Post-harvest technologies (agro-processing, storage)	

41. What are the hindrances for use of adaptation options of combating climate change?

1. Lack of money to finance 2. Lack of technical knowledge 3. Lack of irrigation
4. Lack of weather information 5. Lack of improved seed variety

42. What are the determinant factors that hinder the perception of climate change/ variability?

1. Distance from market 2. Lack of infrastructure 3. Poor communication with DAs 4. Lack of information

43. How do you conserve feed for your livestock?

1. No conservation 2.Bale hay 3.Make silage 4.Other (specify) ___________________

44. Have you collected livestock manure from your farm in the last 12 months?

1. Yes 2. No

45. If YES, how do you manage the manure produced by your livestock?

1. Cover in a pit 2. Collect under shade 3. Collect uncovered in the open 4. Compost it 5. Discard in surrounding area 6. Add ash 7. Other _____________

46. How do you have access to climate change information?

1. Low 2. Medium 3. High

47. Do you perceive that there is climate change and it is adversely impact on crop production? 1. Yes 2. No

Annex 2: Key informant interview guide

KII check list

Respondent Name __________________________ Position____________________

Organization____________________________

Mobile Number ____________________________ Date ____________________

1. What is your perception about climate smart agriculture?

----

2. What challenges do you experience with using CSA practices/technologies?

----

3. What are your perceptions about the effects of climate change? What is your perception of climate change mitigation and adaptation?

----

4. Are you aware of any policy and legal frameworks in place that promote the participation in climate change mitigation and adaptation?

----

5. What is the main obstacle to obtaining sufficient food for the household?

----

6. What are the most important crops in the *kebele*? What varieties of these crops are available?

----

7. What are the characteristics of each variety and which characteristics are the most important for productivity and food security?

----

8. What are the most important climatic events during the year? How have these events changed in recent years?

----

9. What are the common crop and livestock management practices? (terracing, mulching, inorganic fertilizer use, compost, farmyard manure, contour plowing, burning, cover crops, green manure, zero tillage, irrigation, intercropping, fallows, crop rotation, agroforestry, reforestation, rainwater harvesting, organic agriculture, ridges/bunds, reduce open grazing, and feed improvement)

----

10. What challenges do farmers mainly face in relation to the following categories?

Categories	Challenge
Climate variability	
Market access	
Input availability	
Credit	
Land access	
Pests and diseases	
Seed supply	
Agricultural inputs	
Land preparation	
Weeding	
Harvesting	
Postharvest	
Transportation	
Marketing	

Annex 3: Focus group discussion guide

FGD check list

1. What is your perception about climate smart agriculture?

----

2. What type of CSA technologies do you adopt? How can the adoption of these improved or climate smart crop production practices is enhanced?

----

3. What challenges do you experience with using CSA practices/technologies?

----

4. What are your perceptions about the effects of climate change on crop production? What is your perception of climate change mitigation and adaptation?

----

5. What are the climate change events or treats in the area during the last decade? (in terms of drought, flood, prolonged dry spell, late on set rains, early end of rain, increased seasonal temperature, increased evaporation).

----

6. What is the main obstacle to obtaining sufficient food for the household?

----

7. What are the improved or climate smart crop production practices promoted by the development partners?

----

8. What are the most important crops in the kebele? What varieties of these crops have been mostly up taken by farmers? What extent of adoption according to your opinion? What encouraged them to adopt?

----

9. What are the challenges of crop productivity to enhance food security?

----

10. What are the major determining factors for adoption of climate smart agriculture practices and how they influence adoption?

Annex 4: SPSS analysis raw data

1. Demographic and socio economic characteristics of the respondent:

Table 4.1: Descriptive analysis of some categorical variables

		Kebele				
Characteristics	Category	Ejersa	Kombolcha	Wele	Total	%
Sex	Male	62	142	129	333	90.5
	Female	6	13	16	35	9.5
	Total	68	155	145	368	100.0
Marital status	single	1	7	10	18	4.9
	married	61	143	124	328	89.1
	divorced	1	1	0	2	.5
	widowed	5	4	11	20	5.4
	polygamous	0	0	0	0	0.0
	Total	68	155	145	368	100.0
Religion	orthodox	66	155	143	364	98.9
	Muslim	2	0	1	3	.8
	protestant	0	0	1	1	.3
	catholic	0	0	0	0	0.0
	Total	68	155	145	368	100.0
Education	illiterate	39	79	86	204	55.4
	Grade1-4	23	42	34	99	26.9
	Grade5-8	3	22	17	42	11.4
	Grades9 -10	3	10	7	20	5.4
	Grade11-12	0	1	1	2	.5
	TVET and above	0	1	0	1	.3
	Total	68	155	145	368	100.0

Table 2: Descriptive analysis of some continues variables

Characteristics	Keble	Descriptive statistic N	Mean	Median	Minimum	Maximum	Sum	SD
Age of the household head in year	Ejersa	68	44.85	46	26	65	3050	8.30
	Kombolcha	155	43.85	42	21	65	6797	10.90
	Wele	145	44.63	44	22	65	6472	11.10
	Total	368	44.35	44	21	65	16319	10.54
Family size_ Male	Ejersa	67	2.85	3	1	9	191	1.33
	Kombolcha	154	2.75	3	1	6	423	1.16
	Wele	144	2.88	3	1	8	414	1.27
	Total	365	2.82	3	1	9	1028	1.23
Family size_ Female	Ejersa	67	2.09	2	1	4	140	.87
	Kombolcha	153	2.30	2	0	7	352	1.20
	Wele	143	2.56	2	1	7	366	1.18
	Total	363	2.36	2	0	7	858	1.15
Family size_ Total	Ejersa	68	4.87	5	1	11	331	1.74
	Kombolcha	155	5.00	5	1	12	775	1.85
	Wele	145	5.34	5	1	12	774	2.08
	Total	368	5.11	5	1	12	1880	1.93
Total farm size of the household in hectares	Ejersa	68	2.00	2.00	.75	3.00	136.20	.64
	Kombolcha	155	1.61	1.50	.25	3.00	250.12	.75
	Wele	145	1.76	1.75	.25	3.00	255.00	.72
	Total	368	1.74	1.75	.25	3.00	641.32	.73
Experience in agriculture in years	Ejersa	68	23.76	22	7	40	1616	7.84
	Kombolcha	155	23.94	23	2	40	3711	10.17
	Wele	145	24.42	24	4	45	3541	10.10
	Total	368	24.10	23	2	45	8868	9.73

Table 3: Household farm information

Household farm Characteristics	Category	Frequency	Percent
Farm slope	Plain	361	98.1
	Hilly	4	1.1
	Steep	3	0.8
	Total	368	100.00
The level of fertility of the farm land	Fertile	56	15.2
	Moderately fertile	293	79.6
	Less fertile	19	5.2
	Total	368	100.00
Does the household possess an irrigated farm?	Yes	14	3.8
	No	354	96.2
	Total	368	100

Table 4: Household crop production and utilization statistics

Parameters	N	Mean	Median	Sum	Min	Max	SD
Land size in Ha(Wheat)	368	.92	1.00	338.25	.25	3.50	.47
Production in 2010/11 in quintals (Wheat)	366	31.56	30.00	11550.00	2.00	109.00	17.18
Sale in quintals(Wheat)	340	17.67	15.00	6008.00	.50	78.00	13.37
Reserve for seed in quintals(wheat)	321	2.99	2.00	959.09	.25	250.00	14.01
Land size in Ha(Teff)	365	.66	.50	239.18	.03	2.00	.39
Production in 2010/11 in quintals (Teff)	363	12.03	10.00	4365.20	1.00	39.00	7.93
Sale in quintals (Teff)	280	7.01	5.00	1962.87	.17	30.00	6.42
Reserve for seed in quintals (Teff)	285	1.61	.50	459.90	.03	200.00	11.96
Land size in Ha (Pulse)	309	.48	.50	.13	3.00	148.83	.30
Production in 2010/11 in quintals (Pulse)	284	6.29	4.00	.00	39.00	1785.40	6.39
Sale in quintals (Pulse)	161	6.07	4.00	.50	23.00	976.50	5.72
Reserve for seed in quintals (Pulse)	170	1.17	1.00	.10	35.00	198.90	2.74

Table 5: Livestock Number of the household

Kebele	Cattle	Valid N	Mean	Median	Minimum	Maximum	Sum	Standard Deviation
Ejersa	Oxen/cow	66	2.47	2	1	6	163	.86
	Heifers	50	1.08	1	1	2	54	.27
	Horse	9	1.00	1	1	1	9	0.00
	Mule	0						
	Donkey	67	1.66	2	1	3	111	.51
	Sheep	62	5.92	5	2	16	367	3.39
	Goat	0						
	Poultry	45	8.04	7	1	20	362	4.20
Kombolcha	Oxen/cow	154	2.87	3	1	7	442	1.09
	Heifers	106	1.18	1	1	2	125	.39
	Horse	76	1.13	1	1	2	86	.34
	Mule	0						
	Donkey	154	1.73	2	1	4	266	.76
	Sheep	132	4.96	4	1	20	655	3.10
	Goat	24	2.83	2	1	7	68	1.93
	Poultry	129	6.17	5	1	26	796	4.78
Wele	Oxen/cow	144	2.92	3	1	6	421	.92
	Heifers	106	1.41	1	1	4	149	.71
	Horse	74	1.30	1	1	5	96	.64
	Mule	1	2.00	2	2	2	2	
	Donkey	140	1.90	2	1	5	266	.90
	Sheep	112	5.37	4	1	20	601	3.49
	Goat	9	3.11	2	1	7	28	2.47
	Poultry	104	7.03	6	1	30	731	5.84
Total	Oxen/cow	364	2.82	3	1	7	1026	1.00
	Heifers	262	1.25	1	1	4	328	.54
	Horse	159	1.20	1	1	5	191	.50
	Mule	1	2.00	2	2	2	2	
	Donkey	361	1.78	2	1	5	643	.78
	Sheep	306	5.30	4	1	20	1623	3.32
	Goat	33	2.91	2	1	7	96	2.05
	Poultry	278	6.79	5	1	30	1889	5.14

Table 6: Access to credit service and purpose of the loan

Characteristics	Category	Frequency	Percent
Do any members of the household have access to credit service in the last	Yes	206	56.0
	No	162	44.0
	Total	368	100.00
What was the main purpose of the loan?	Purchase farm inputs (e.g. seeds, fertilizers)	184	89.3
	Buy livestock	13	6.3
	Buy land	8	3.9
	Construction of farm structures	1	0.5
	Total	206	100

Table 7.1: Agricultural extension agents

Characteristics	Category	Frequency	Percent
Do you have contact with agricultural extension agents?	Yes	360	97.8
	No	8	2.2
	Total	368	100.00

Table 7.2: Frequency of meeting with extension agents

	N	Mean	Median	Minimum	Maximum	Sum	SD
how many times do you usually meet with extension agents	360	5.57	4	1	32	2006	5.13

Table 8: Market distance

How far is the nearest market from your farm? --------------- Kilo meter	
N Valid	368
Mean	5.949
Median	5.000
Std. Deviation	3.8535
Range	19.8
Minimum	.2
Maximum	20.0

Table 9: Weather information and farming system of the household respondents

Characteristics	Category	Frequency	Percent
Do you have a regular access to weather information	Yes	270	75.5
	No	90	24.5
	Total	368	100.00
Which farming systems are you carry out for living?	Only crop production	71	19.3
	Mixed farming	297	80.7
	Total	368	100

Table 10.1: Farming system; by sex

		Sex of the household head					
		male		female		Total	
farming systems	Only crop production	66	19.8%	5	14.3%	71	19.3%
	Livestock rearing	0	0.0%	0	0.0%	0	0.0%
	Mixed farming	267	80.2%	30	85.7%	297	80.7%
	Total	333	100.0%	35	100.0%	368	100.0%

Table 10.2: Farming system; by kebele

		Kebele							
		Ejersa		Kombolcha		Wele		Total	
Farming System	Only crop production	0	0.0%	8	5.2%	63	43.4%	71	19.3%
	Livestock rearing	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Mixed farming	68	100.0%	147	94.8%	82	56.6%	297	80.7%
	Total	68	100.0%	155	100.0%	145	100.0%	368	100.0%

2. Adoption of climate smart agriculture

Table 11: Challenges/problems of climate change affect agriculture and severity of the climate problem

Severity of the climate problem	Frequency	Percent	Valid Percent	Cumulative Percent
Very high	38	13.2	13.2	13.2
High	67	23.3	23.3	36.6
Medium	99	34.5	34.5	71.1
Low	47	16.4	16.4	87.5
Very low	36	12.5	12.5	100.0
Total	287	100.0	100.0	

Climate problems	Category	Count	Percent
Flooding	yes	68	18.48
	no	300	81.52
	Total	368	100.00
Drought	yes	51	13.86
	no	317	86.14
	Total	368	100.00
Late onset	yes	54	14.67
	no	314	85.33
	Total	368	100.00
Early onset	yes	52	14.13
	no	316	85.87
	Total	368	100.00
Early ending of rainfall	yes	109	29.62
	no	259	70.38
	Total	368	100.00
High temperature	yes	43	11.68
	no	325	88.32
	Total	368	100.00
Very cold temperature (wurch)	yes	203	55.16
	no	165	44.84
	Total	368	100.00

Table 12: Aware of climate smart agriculture and adopting climate smart agriculture practices by kebele

			Ejersa	Kombolcha	Wele	Total	
Climate category	Parameters	Category	Count	Count	Count	Count	%
	Did you or any household member have had information/training on how to use climate smart agriculture?	yes	7	93	118	218	59.24
		no	61	62	27	150	40.76
		Total	68	155	145	368	100.00
Conservation Agriculture	Reduced tillage	yes	0	61	33	94	25.54
		no	68	94	112	274	74.46
		Total	68	155	145	368	100.00
	Crop residue management	yes	10	71	70	151	41.03
		no	58	84	75	217	58.97
		Total	68	155	145	368	100.00
	Mulching	yes	1	10	37	48	13.04
		no	67	145	108	320	86.96
		Total	68	155	145	368	100.00
	Crop rotation	yes	59	98	107	264	71.74
		no	9	57	38	104	28.26
		Total	68	155	145	368	100.00
Integrated soil fertility management	Compost and manure management including green manure	yes	11	67	24	102	27.72
		no	57	88	121	266	72.28
		Total	68	155	145	368	100.00
	Efficient fertilizer application techniques(time, method, amount)	yes	61	136	132	329	89.40
		no	7	19	13	39	10.60
		Total	68	155	145	368	100.00
Small scale irrigation:	Year-round cropping	yes	0	26	13	39	10.60
		no	68	129	132	329	89.40
		Total	68	155	145	368	100.00
	Efficient water utilization	yes	1	11	12	24	6.52
		no	67	144	133	344	93.48
		Total	68	155	145	368	100.00
Agro-forestry	Tree-based conservation agriculture	yes	1	38	22	61	16.58
		no	67	117	123	307	83.42
		Total	68	155	145	368	100.00
	Practiced both traditionally and as	yes	10	58	94	162	44.02
		no	58	97	51	206	55.98

			Ejersa	Kombolcha	Wele	Total	
Climate category	Parameters	Category	Count	Count	Count	Count	%
	improved practice	Total	68	155	145	368	100.00
	Farmer-managed natural regeneration	yes	2	61	78	141	38.32
		no	66	94	67	227	61.68
		Total	68	155	145	368	100.00
Crop diversification Improved seed:	Popularization of new crops and crop varieties	yes	58	127	92	277	75.27
		no	10	28	53	91	24.73
		Total	68	155	145	368	100.00
	Pest resistance, high yielding, tolerant to drought, short season	yes	63	107	115	285	77.45
		no	5	48	30	83	22.55
		Total	68	155	145	368	100.00
Improved livestock feed and feeding practices:	Reduced open grazing/zero grazing	yes	38	71	39	148	40.22
		no	30	84	106	220	59.78
		Total	68	155	145	368	100.00
	Forage development and rangeland management	yes	15	41	31	87	23.64
		no	53	114	114	281	76.36
		Total	68	155	145	368	100.00
	Feed improvement	yes	23	69	85	177	48.10
		no	45	86	60	191	51.90
		Total	68	155	145	368	100.00
	Livestock breed improvement and diversification	yes	41	90	101	232	63.04
		no	27	65	44	136	36.96
		Total	68	155	145	368	100.00
	Water harvesting	yes	0	25	10	35	9.51
		no	68	130	135	333	90.49
		Total	68	155	145	368	100.00
	Early-warning systems and improved weather information	yes	8	51	49	108	29.35
		no	60	104	96	260	70.65
		Total	68	155	145	368	100.00
	Livelihoods diversification(api culture, aquaculture)	yes	1	14	6	21	5.71
		no	67	141	139	347	94.29
		Total	68	155	145	368	100.00
	Post-harvest technologies(agro-processing, storage)	yes	24	81	111	216	58.70
		no	44	74	34	152	41.30
		Total	68	155	145	368	100.00

3. Institutional Characteristics

Table 13: Access to credit service and purpose of loan by sex

Characters	Category	Sex of the household head					
		male		female		Total	
Access to credit service	yes	185	55.6	21	60.0	206	56.0
	no	148	44.4	14	40.0	162	44.0
	Total	333	100.0	35	100.0	368	100.0
The main purpose of the loan	Purchase farm inputs (e.g. seeds, fertilizers)	163	88.1	21	100.0	184	89.3
	Buy livestock	13	7.0	0	0.0	13	6.3
	Buy land	8	4.3	0	0.0	8	3.9
	Construction of farm structures	1	.5	0	0.0	1	.5
	Buy machinery and equipment	0	0.0	0	0.0	0	0.0
	Payment of labor costs	0	0.0	0	0.0	0	0.0
	Other	0	0.0	0	0.0	0	0.0
	Total	185	100.0	21	100.0	206	100.0

Table 14: Extension agents & frequency of meeting; and participation of farm field day

Characteristic	Category	Frequency	Percent	Valid
participation of farm field day	yes	300	81.5	81.5
	no	68	18.5	18.5
	Total	368	100	100
contact with agricultural extension agents	yes	360	97.8	97.8
	no	8	2.2	2.2
	Total	368	100	100

	N	Mean	Median	Minimum	Maximum	Sum	SD
frequency of meeting with agricultural extension agents	360	5.57	4	1	32	2006	5.13

Table 15: Distance to market; weather information & climate change information

	N	Mean	Median	Minimum	Maximum	SD
How far is the nearest market from your farm? ------------- Kilo meter	368	5.9	5.0	.2	20.0	3.9

Characteristics	Category	Frequency	Percent	Percent
weather information	yes	278	75.5	75.5
	no	90	24.5	24.5
	Total	368	100	100
climate change information	Low	245	66.6	66.6
	Medium	117	31.8	31.8
	High	6	1.6	1.6
	Total	368	100	100

Annex 5: Rainfall and temperature distribution

Table 5.1: Monthly Minimum Temperature distribution in Siyadeberina wayu woreda

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	8.60	9.68	10.63	10.17	10.10	9.81	9.87	9.81	9.64	8.98	8.34	7.93	9.46
1988	9.54	10.85	11.31	10.54	11.09	10.87	10.39	10.16	9.60	7.99	6.00	6.51	9.57
1989	7.07	8.89	9.78	10.57	10.20	10.19	9.97	9.84	10.09	7.80	6.82	8.52	9.14
1990	7.66	9.99	9.41	9.98	10.08	9.75	9.98	10.30	9.74	7.07	6.82	5.95	8.89
1991	8.30	9.21	10.05	10.73	10.55	9.89	9.99	9.98	9.65	7.49	7.49	6.97	9.19
1992	9.28	9.83	9.77	9.62	10.37	10.32	10.28	10.50	9.51	8.09	7.16	7.45	9.35
1993	8.63	9.49	9.24	10.28	10.36	10.08	10.40	10.78	10.26	8.65	6.68	7.29	9.34
1994	8.19	8.95	10.33	10.87	11.00	10.81	10.31	10.42	9.85	7.98	6.83	6.62	9.35
1995	7.62	9.55	9.80	10.76	10.57	10.54	10.23	10.43	9.77	7.90	7.23	8.54	9.41
1996	9.36	9.15	9.93	10.35	10.62	10.17	10.03	10.03	10.28	7.60	7.16	7.00	9.31
1997	9.35	8.23	10.71	10.53	10.79	11.10	10.28	10.49	10.37	9.45	8.24	7.19	9.73
1998	9.59	10.63	11.22	11.83	11.56	11.05	10.78	10.93	10.25	9.03	6.32	5.86	9.92
1999	7.84	8.60	10.00	10.09	10.95	10.58	10.28	10.29	9.73	8.45	5.90	6.66	9.11
2000	6.66	8.19	9.30	9.98	11.21	10.53	10.12	10.21	9.94	7.94	7.14	7.04	9.02
2001	7.55	9.08	10.26	10.32	10.72	10.46	10.34	10.75	9.89	8.49	7.56	7.83	9.44
2002	8.51	9.28	10.37	10.36	11.28	10.61	10.84	10.51	10.24	8.50	7.38	9.09	9.75
2003	8.69	9.79	10.16	11.19	11.97	10.97	10.67	11.00	10.26	8.22	7.64	7.31	9.82
2004	9.71	9.61	10.25	11.08	10.99	10.78	10.63	11.03	9.88	7.73	6.97	7.68	9.69
2005	8.08	9.93	10.75	11.14	11.05	10.62	10.42	10.66	10.23	7.95	6.75	6.00	9.46
2006	8.35	9.75	10.15	10.45	10.82	10.75	10.66	10.62	9.95	8.98	7.25	7.77	9.62
2007	8.95	9.44	10.15	10.80	11.70	11.06	10.58	10.36	10.08	7.66	7.24	5.53	9.46
2008	8.50	7.25	9.63	10.81	10.08	9.71	9.80	10.53	10.13	8.53	6.95	7.34	9.10
2009	8.64	9.54	10.41	11.26	11.55	11.72	10.49	10.92	10.19	8.75	7.21	8.48	9.93
2010	8.78	10.99	10.72	11.64	12.10	11.73	10.60	11.00	10.06	8.44	7.45	7.65	10.09
2011	8.82	8.64	9.75	11.12	11.09	10.94	10.13	9.98	9.81	7.87	7.89	6.59	9.38
2012	7.59	7.77	9.33	10.82	10.62	10.83	10.36	10.33	9.97	7.55	7.34	7.49	9.17
2013	8.63	9.65	11.27	11.23	11.55	11.07	10.52	10.48	9.93	8.30	7.16	6.02	9.65
2014	8.61	9.62	10.32	10.42	10.62	10.54	10.76	10.03	10.05	8.08	7.03	6.73	9.40
2015	8.89	9.48	10.51	11.31	11.6	11.3	10.8	10.9	10.3	8.5	7.3	7.1	9.83
2016	8.93	9.50	10.54	11.36	11.6	11.4	10.8	10.9	10.3	8.5	7.3	7.1	9.86
2017	8.97	9.52	10.57	11.41	11.6	11.4	10.9	11.0	10.3	8.6	7.3	7.1	9.89
Total	8.51	9.36	10.21	10.74	10.98	10.69	10.39	10.49	10.01	8.23	7.16	7.17	9.49

Table 5.2: Monthly Maximum Temperature distribution in Siyadeberina wayu woreda

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	21.31	21.51	21.33	21.46	21.28	21.78	21.04	18.99	20.56	21.53	21.93	22.30	21.25
1988	22.82	22.58	23.54	23.11	23.75	22.68	17.91	18.09	18.83	20.23	21.27	21.25	21.34
1989	20.94	21.67	21.90	21.05	22.17	22.48	19.29	18.37	19.10	20.40	21.46	20.88	20.81
1990	21.19	20.54	21.34	21.61	22.69	22.92	18.49	18.74	19.47	20.15	21.06	20.97	20.76
1991	21.29	21.67	22.09	23.38	22.09	21.90	18.35	17.86	19.72	20.96	21.81	21.21	21.03
1992	20.86	21.46	23.39	22.47	23.55	23.12	18.34	17.34	18.98	20.43	20.73	21.34	21.00
1993	21.40	21.80	23.51	22.17	21.84	22.23	18.43	18.76	19.23	20.77	21.71	21.84	21.14
1994	22.83	23.74	23.49	24.07	24.27	22.89	17.85	17.65	18.76	20.54	21.12	22.03	21.60
1995	22.51	23.12	23.53	22.20	23.11	23.03	18.29	17.90	19.26	20.03	20.86	21.62	21.29
1996	20.68	22.55	22.48	22.50	21.54	20.88	19.18	19.14	20.88	20.77	20.72	21.02	21.03
1997	21.48	22.64	23.19	21.93	22.54	22.23	18.60	18.53	20.16	20.46	21.19	21.68	21.22
1998	22.24	23.31	23.43	24.62	23.71	23.82	18.10	17.66	19.46	20.45	20.94	21.00	21.56
1999	21.65	23.26	23.43	24.01	24.32	23.94	17.48	17.90	19.52	19.85	20.57	21.27	21.43
2000	22.65	23.44	24.64	23.27	23.84	23.37	18.53	17.64	19.59	20.20	20.94	21.65	21.65
2001	21.87	23.31	21.48	23.39	23.20	22.04	18.35	17.80	20.39	21.31	21.10	21.61	21.32
2002	21.13	23.26	22.53	23.22	24.52	23.09	19.75	18.12	19.93	21.15	21.60	21.43	21.64
2003	22.08	23.70	23.84	23.40	25.02	23.24	18.07	17.90	19.76	21.04	21.67	21.76	21.79
2004	23.20	23.68	23.73	22.77	24.71	22.68	18.51	18.25	20.08	20.34	21.27	21.88	21.76
2005	21.98	24.63	24.27	23.96	22.53	22.83	18.23	18.91	20.15	20.69	21.13	21.55	21.74
2006	22.80	23.80	23.23	22.15	23.55	23.65	18.92	17.93	19.60	21.28	21.47	21.27	21.64
2007	22.74	22.90	24.25	23.16	24.55	22.37	17.98	18.04	19.63	20.42	21.04	21.41	21.54
2008	22.55	22.87	24.83	23.34	24.34	22.58	19.08	18.17	20.16	20.93	20.42	21.20	21.70
2009	21.86	22.83	24.03	24.16	24.83	24.97	17.79	18.41	20.68	20.89	21.59	20.42	21.87
2010	22.08	23.69	23.72	23.80	23.14	23.69	19.29	18.76	19.98	21.27	21.39	21.47	21.86
2011	22.11	23.99	22.57	23.97	23.27	23.30	19.97	18.83	20.14	20.91	21.47	21.79	21.86
2012	22.46	23.32	23.80	22.53	22.68	23.54	18.70	18.33	20.33	21.25	22.66	22.13	21.81
2013	23.30	24.68	24.81	25.03	24.33	23.34	18.15	17.67	20.35	20.46	21.51	21.45	22.09
2014	22.89	23.25	23.76	22.96	23.15	23.71	20.01	17.94	19.90	20.93	21.69	21.23	21.79
2015	22.51	23.97	24.08	23.79	24.14	23.63	18.27	17.93	20.14	20.74	21.21	21.34	21.81
2016	22.53	24.03	24.12	23.84	24.20	23.68	18.23	17.91	20.16	20.74	21.19	21.33	21.83
2017	22.56	24.10	24.17	23.88	24.25	23.73	18.19	17.88	20.18	20.74	21.18	21.32	21.85
Total	22.08	23.07	23.37	23.13	23.45	23.01	18.62	18.17	19.84	20.70	21.29	21.44	21.52

Table 5.3: Trends of annual distribution of temperatures in Siyadeberina wayu woreda

Year	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Range (Max. - Min.) Temperature (°C)
1987	9.46	21.25	15.36	11.79
1988	9.57	21.34	15.45	11.77
1989	9.14	20.81	14.98	11.66
1990	8.89	20.76	14.83	11.87
1991	9.19	21.03	15.11	11.84
1992	9.35	21.00	15.17	11.65
1993	9.34	21.14	15.24	11.80
1994	9.35	21.60	15.47	12.26
1995	9.41	21.29	15.35	11.88
1996	9.31	21.03	15.17	11.72
1997	9.73	21.22	15.47	11.49
1998	9.92	21.56	15.74	11.64
1999	9.11	21.43	15.27	12.32
2000	9.02	21.65	15.33	12.63
2001	9.44	21.32	15.38	11.88
2002	9.75	21.64	15.70	11.90
2003	9.82	21.79	15.80	11.97
2004	9.69	21.76	15.73	12.06
2005	9.46	21.74	15.60	12.27
2006	9.62	21.64	15.63	12.01
2007	9.46	21.54	15.50	12.08
2008	9.10	21.70	15.40	12.60
2009	9.93	21.87	15.90	11.94
2010	10.09	21.86	15.98	11.76
2011	9.38	21.86	15.62	12.48
2012	9.17	21.81	15.49	12.64
2013	9.65	22.09	15.87	12.44
2014	9.40	21.79	15.59	12.38
2015	9.83	21.81	15.82	11.98
2016	9.86	21.83	15.84	11.97
2017	9.89	21.85	15.87	11.96

Table 5.4: Seasonal and annual rainfall distribution in Siyadeberina wayu woreda

Year		Belg				Kiremt				Bega			Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1987	0.00	32.78	157.50	84.36	144.26	89.57	173.48	228.44	50.42	1.36	0.39	5.38	967.93
1988	12.37	59.47	2.14	67.98	9.26	57.73	397.85	306.35	133.83	6.85	0.00	0.00	1053.83
1989	10.64	50.16	50.89	83.75	6.87	45.16	214.83	261.56	74.39	21.21	0.00	39.80	859.24
1990	0.00	72.62	34.64	14.93	0.95	0.12	354.90	213.71	161.31	0.00	0.00	0.00	853.17
1991	6.33	21.42	66.11	6.31	8.42	62.31	297.65	289.96	93.15	2.51	0.00	4.61	858.77
1992	28.62	56.16	46.00	56.98	17.27	32.09	233.43	201.08	101.97	16.44	2.17	1.69	793.87
1993	9.35	29.19	27.54	124.39	51.74	39.52	353.65	202.18	121.48	11.82	0.00	0.00	970.86
1994	0.00	0.66	75.36	27.24	13.25	82.53	285.89	191.11	126.36	0.00	12.28	0.00	814.68
1995	0.00	31.37	39.91	108.01	35.93	29.85	315.46	276.77	62.14	0.00	0.00	25.97	925.41
1996	32.34	8.18	104.43	35.26	89.83	204.60	362.54	277.96	52.66	0.23	19.06	0.00	1187.07
1997	32.95	0.00	37.93	29.77	15.06	131.72	323.55	225.46	40.04	63.80	34.81	0.00	935.06
1998	22.23	15.75	37.03	52.28	59.00	41.00	324.02	294.73	108.06	30.31	0.00	0.00	984.41
1999	5.05	0.00	19.31	4.91	3.89	43.78	403.69	348.39	70.55	51.33	0.09	0.08	951.06
2000	0.00	0.00	18.86	88.57	41.91	48.63	350.59	292.14	101.72	12.96	8.42	1.08	964.87
2001	0.00	10.41	99.78	28.57	73.01	84.66	413.00	218.96	38.31	0.00	0.00	10.44	977.12
2002	34.96	41.37	58.59	25.91	1.52	38.83	243.78	213.62	68.56	0.05	0.00	7.95	735.14
2003	14.05	40.90	44.24	99.12	3.37	91.17	321.87	283.03	99.22	0.02	0.47	7.33	1004.77
2004	14.87	8.37	58.03	110.60	10.99	137.37	278.40	271.80	99.18	11.43	5.26	0.90	1007.19
2005	25.22	0.10	40.63	77.85	67.57	82.81	289.03	258.56	93.37	0.00	0.00	0.00	935.13
2006	11.40	23.97	120.58	52.13	47.78	64.27	434.11	282.55	106.82	8.81	0.00	11.32	1163.73
2007	8.95	34.17	51.06	70.16	33.94	102.96	355.72	379.89	130.41	1.83	0.14	0.00	1169.22
2008	1.00	0.01	34.30	34.52	49.84	123.64	357.12	256.71	71.09	6.24	58.45	0.00	992.91
2009	18.06	3.85	21.90	24.39	23.80	17.22	399.45	368.42	54.40	39.54	0.29	20.36	991.66
2010	5.84	42.60	69.80	91.04	98.46	45.90	334.39	322.98	90.72	0.00	16.27	10.84	1128.83
2011	10.67	0.00	76.35	47.32	66.56	75.93	313.89	321.05	123.24	0.00	9.54	0.00	1044.55
2012	0.00	0.00	51.57	101.21	30.06	100.60	427.87	344.06	82.04	0.00	0.25	0.00	1137.65
2013	0.00	0.00	35.67	48.36	22.80	68.68	318.65	289.89	88.83	48.50	0.56	0.00	921.93
2014	0.45	27.50	48.79	40.72	83.16	41.29	311.00	306.75	115.98	13.54	0.46	0.00	989.63
2015	10.44	9.15	51.19	59.24	33.58	71.76	243.89	311.12	87.08	15.45	9.68	4.23	1020.65
2016	10.45	8.41	50.98	59.27	32.78	71.57	242.17	313.17	86.70	15.67	9.95	4.20	1022.61
2017	10.46	7.67	50.78	59.29	31.99	71.38	240.44	315.22	86.31	15.89	10.21	4.18	1024.56
Ave.	10.86	20.52	54.25	58.53	38.99	70.92	319.88	279.60	90.98	12.77	6.41	5.17	**980.24**
Max.	34.96	72.62	120.58	124.39	144.26	204.60	434.11	379.89	161.31	63.80	58.45	39.80	1187.07
Min.	0.00	0.00	2.14	4.91	0.95	0.12	173.48	191.11	38.31	0.00	0.00	0.00	735.14
SD	3.1	4.56	12.53	9.82	7.74	12.99	23.24	37.51	13.67	3.64	2.05	2.18	108.82
CV	25.3	20.20	27.33	23.39	33.96	21.93	7.47	13.61	16.34	26.89	27.46	28.25	**11.10**
PCI													**21.07**

Table 5.5: Annual and Seasonal average rainfall, standard deviation, and coefficient of variation

Year	Rainfall		
	Annual	Belg	Kiremt
1987	967.93	418.90	541.91
1988	1053.83	138.85	895.76
1989	859.24	191.66	595.94
1990	853.17	123.14	730.03
1991	858.77	102.25	743.07
1992	793.87	176.41	568.56
1993	970.86	232.85	716.83
1994	814.68	116.51	685.89
1995	925.41	215.22	684.22
1996	1187.07	237.69	897.76
1997	935.06	82.75	720.76
1998	984.41	164.06	767.82
1999	951.06	28.10	866.41
2000	964.87	149.33	793.08
2001	977.12	211.77	754.92
2002	735.14	127.38	564.80
2003	1004.77	187.63	795.28
2004	1007.19	187.98	786.75
2005	935.13	186.15	723.77
2006	1163.73	244.46	887.75
2007	1169.22	189.33	968.98
2008	992.91	118.67	808.56
2009	991.66	73.93	839.50
2010	1128.83	301.90	793.99
2011	1044.55	190.23	834.11
2012	1137.65	182.84	954.56
2013	921.93	106.82	766.04
2014	989.63	200.16	775.02
2015	1020.65	153.16	713.86
2016	1022.61	151.44	713.60
2017	1024.56	149.73	713.35
Mean	980.24	172.30	761.38
SD	108.82	72.54	106.16
CV	11.10	42.10	13.94

Table 5.6: Drought severity of annual and seasonal rainfall,

Year	Annual rainfall		Drought severity	Belg season rainfall		Drought severity	Kiremt season rainfall		Drought severity
	Xi	Xi -x̄	Xi -x̄/SD	Xi	Xi -x̄	Xi -x̄/SD	Xi	Xi -x̄	Xi -x̄/SD
1987	967.93	-12.31	-0.11	418.90	246.60	3.40	541.91	-219.49	-2.07
1988	1053.83	73.59	0.68	138.85	-33.45	-0.46	895.76	134.36	1.27
1989	859.24	-121.00	-1.11	191.66	19.36	0.27	595.94	-165.46	-1.56
1990	853.17	-127.07	-1.17	123.14	-49.16	-0.68	730.03	-31.37	-0.30
1991	858.77	-121.47	-1.12	102.25	-70.05	-0.97	743.07	-18.33	-0.17
1992	793.87	-186.37	-1.71	176.41	4.11	0.06	568.56	-192.84	-1.82
1993	970.86	-9.38	-0.09	232.85	60.55	0.84	716.83	-44.57	-0.42
1994	814.68	-165.56	-1.52	116.51	-55.79	-0.77	685.89	-75.51	-0.71
1995	925.41	-54.83	-0.50	215.22	42.92	0.59	684.22	-77.18	-0.73
1996	1187.07	206.83	1.90	237.69	65.39	0.90	897.76	136.36	1.28
1997	935.06	-45.18	-0.42	82.75	-89.55	-1.24	720.76	-40.64	-0.38
1998	984.41	4.16	0.04	164.06	-8.24	-0.11	767.82	6.41	0.06
1999	951.06	-29.18	-0.27	28.10	-144.20	-1.99	866.41	105.01	0.99
2000	964.87	-15.38	-0.14	149.33	-22.97	-0.32	793.08	31.68	0.30
2001	977.12	-3.12	-0.03	211.77	39.47	0.54	754.92	-6.48	-0.06
2002	735.14	-245.10	-2.25	127.38	-44.92	-0.62	564.80	-196.60	-1.85
2003	1004.77	24.53	0.23	187.63	15.33	0.21	795.28	33.88	0.32
2004	1007.19	26.94	0.25	187.98	15.68	0.22	786.75	25.35	0.24
2005	935.13	-45.11	-0.41	186.15	13.85	0.19	723.77	-37.64	-0.35
2006	1163.73	183.49	1.69	244.46	72.16	1.00	887.75	126.35	1.19
2007	1169.22	188.98	1.74	189.33	17.03	0.23	968.98	207.58	1.95
2008	992.91	12.67	0.12	118.67	-53.63	-0.74	808.56	47.16	0.44
2009	991.66	11.42	0.10	73.93	-98.37	-1.36	839.50	78.10	0.74
2010	1128.83	148.59	1.37	301.90	129.60	1.79	793.99	32.59	0.31
2011	1044.55	64.31	0.59	190.23	17.93	0.25	834.11	72.71	0.68
2012	1137.65	157.41	1.45	182.84	10.54	0.15	954.56	193.16	1.82
2013	921.93	-58.31	-0.54	106.82	-65.48	-0.90	766.04	4.64	0.04
2014	989.63	9.39	0.09	200.16	27.86	0.38	775.02	13.61	0.13
2015	1020.65	40.41	0.37	153.16	-19.14	-0.26	713.86	-47.54	-0.45
2016	1022.61	42.36	0.39	151.44	-20.86	-0.29	713.60	-47.80	-0.45
2017	1024.56	44.32	0.41	149.73	-22.57	-0.31	713.35	-48.05	-0.45
Mean	980.24			172.30			761.38		
SD	108.82			72.54			106.16		
CV	11.10			42.10			13.94		