PERCEPTIONS OF SMALLHOLDER FARMERS ON POTENTIAL ROLES OF CONSERVATION AGRICULTURE FOR FOOD SECURITY AND CLIMATE CHNGE ADADPTATION IN LOKA ABAYA DISTRICT, SIDAMA ZONE, SOUTHERN ETHIOPIA

M.Sc. Thesis

YOHANNES BATISO

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

JUNE 2018

PERCEPTIONS OF SMALLHOLDER FARMERS ON POTENTIAL ROLES OF CONSERVATION AGRICULTURE FOR FOOD SECURITY AND CLIMATE CHNGE ADADPTATION IN LOKA ABAYA DISTRICT, SIDAMA ZONE, SOUTHERN ETHIOPIA

M.Sc. Thesis

YOHANNES BATISO

MAJOR ADVISOR: GIRMA ABERA (PhD)

CO-ADVISOR: TAREKEGN YOSEPH (PhD)

A THESISSUBMITTED TO THE PROGRAM OF CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE
COLLEGE OF AGRICULTURE,
HAWASSA UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

MAY 2018

HAWASSA UNIVERSITY

ADVISORS APPROVAL SHEET

HAWASSA UNIVERSITY

COLLEGE AGRICULTURE

(Submission Sheet-1)

This is to certify that the thesis entitled ‘’ **Perceptions Of Smallholder Farmers On Potential Roles of Conservation Agriculture for Food Security and Climate Change Adaptation in Loka Abaya District of Sidama Zone”,** submitted in partial fulfillment of the requirements for the degree of masters of Science in **climate change and sustainable agriculture**, and has been carried out by Yohannes Batiso, under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Approved by Advisors;

GIRMA ABERA (PhD)	___________________	_________________
Name of major advisor	Signature	Date
TAREKEGN YOSEPH (PhD)	__________________	_________________
Name of co-advisor	Signature	Date

DEDICATION

I dedicate this thesis manuscript to my father BATISO URAGO and my mother KAFALE BARASA, for nursing me with affection and love and for their dedicated partnership in the success of my life

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this thesis. All scholarly matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

This thesis is submitted in partial fulfillment of the requirement for a degree from the School of Graduate Studies at Hawassa University. The thesis is deposited in the HawassaUniversity Library and is made available to borrowers under the rules of the library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Brief quotations from this thesis may be used without special permission provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from, or reproduction of, this thesis in whole or in part may be granted by the Head of the School or Department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the thesis.

Name: Yohannes Batiso: **Signature**---------------------

Place: Hawassa University, College Agriculture, Hawassa
Date of Submission--------------------------------

.

ACKNOWLEDGEMENT

Above all, I would like to honor and thank the Supreme, Almighty God, without whom anything is impossible. First and foremost, I would like to extend my deepest and heartfelt appreciation to my major advisor Dr. Girma Abera for his unreserved guidance and supervision throughout my research work. Without his critical comments, devotion and encouragement the successful completion of this thesis would have not been possible. Likewise, I would like to admire my co-advisor Dr. TarekegnYoseph for his constructive comments, suggestions, and invaluable editions of my thesis paper.

My appreciations goes to Tekle Jomba, Boricha administer, for his encouragement and offering me the opportunity to pursue my Msc degree program. Many thanks also go to my elder brother Solomon Batiso and Fantu Osman for their brotherly and sisterly encouragement, ideal, material and financial support.

I also extend special thanks to my beloved wife Mrs.Yirgalem Tadesse and my son, Miracle Yohannes for their patience, moral, physical and spiritual support when I have been passing most of my time on thesis work. Lastly yet importantly, I am also grateful to Climate Smart Agriculture (CSA) Project (Hawassa University) for the necessary financial supports to conduct the study. And I would like to thank the Ethiopia Metrology Agency for their cooperation to give me valuable secondary data about rainfall and temperature for past 30 years.

Many thanks also goes to all data collectors especially Mr. Dereje Dumara and Aschalew Megersa and also all smallholder farming rural sample respondents, key informants and group discussion participants for the devotion of their time and energy to share their experiences and knowledge during my field survey.

TABLE OF CONTENTS

CONTENTS **PAGE**

LIST OF FIGURES

Figures **page**

LIST OF TABLES

Table **Page**

LIST OF ABBREVIATIONS AND ACRONOMYS

CA	**Conservation Agriculture**
CC	**Climate Change**
CT	**Conventional Tillage**
CP	**Conventional Agriculture**
CSA	**Climate Smart Agriculture**
CSA	**Central Statistical Agency**
DCG	**Dry land Coordination Group**
FGD	**Focus Group Discussion**
HARC	**Hawassa Agricultural Research Centre**
HU	**Hawassa University**
FAO	**Food and Agricultural Organization**
GOs	**Government Organization**
IPCC	**Intergovernmental Panel on Climate change**
KII	**Key Informant Interview**
NGOs	**Non Governmental Organization**
SIMLESA	**Sustainable Intensification of Maize and Legumes in Eastern and Southern Africa**
SOC	**Soil Organic Carbon**
SOM	**Soil Organic Matter**
SLM	**Sustainable Land Management**
SNNPR	**South Nation Nationalities and Peoples Region**
RTS	**Returns to Scale**
VIF	**Variance Inflation Factor**
WAO	**Woreda Agricultural Organization**

Perceptions of Small holder Farmers on Potential Roles of Conservation Agriculture for Food Security and Climate Change Adaptation in Loka Abaya District, Sidama Zone, Southern Ethiopia

Yohannes Batiso (Bsc), Girma Abera (PhD) and Tarekegn Yoseph (PhD)

ABSTRACT

The study assessed the Perceptions of smallholder farmers on the potential roles of conservation agriculture (CA) for food security and adaptation to climate change. A combination of multi stage purposive and simple random sampling techniques was employed to get a total of 144 sample respondents'. Data were collected from both primary and secondary sources. The primary data were collected by interviewing 144 smallholder household heads, focus group discussions which had total of 10 focus groups with 2 focus group in each Kebeles having 6 household head members in each group, and 32 key informants, which included 10 DAs, 20 elders and 2 officials from district. The secondary data were collected from National Metrological Agency of Ethiopia for 30 years. The collected data were analyzed through descriptive statistics like mean, standard deviation, maximum, minimum, percentage, Chi-square and independent T-test to identify variables that vary significantly between groups and Econometrics such as binary logistic regression model and multiple linear regressions by SPSS version 20. To assess the contribution of CA on food security among smallholder households, the study compared estimated production function between adopters and non- adopters of CA by using Cob-Douglas production function. Secondly, the study used descriptive statistics to assess the roles of CA on climate change adaptation and finally, a binary logistic regression model was used to determine factors that affected the adoption of CA among smallholder farmers. The results showed significant difference in the number of years of schooling, availability of CA training, and access to extension services, soil fertility status, and availability of CA incentives among interviewed households. The results revealed that adoption of CA technology improved household's maize productivity by 45% than those who practiced non-CA. Cobb-Douglas production estimates showed that CA adopters had more than 45% higher maize productivity than that of non-adopters. In addition, there were greater than proportionate unit increases in maize yield with unit increase in land size and labor among CA adopters. According to the reports of respondents, CA enhanced adaptation capacity to the impacts of climate change for adopter than non adopters by increasing soil fertility, reducing production costs (cost of labor and chemical fertilizer) by 94.5%, reducing soil erosion by 80.6%, enhancing soil moisture saving capacity by97.2%, increasing yield and improving crop resilience to the impacts of climate change by 75% in the study area. From the binary logistic regression model results, access to CA training, increase in the number of extension visits, availability of CA incentives, increase in soil fertility increased the adoption of CA technology by 86.98%, 24.8%, 21.1% and 7.0% respectively. The study recommends that there should be improvement in the access to informal elder education, informal training and field demonstration to improve and enhance the acquisition and understanding of CA technology components. Furthermore, adopter households who had better extension service have 45% greater maize yield, 90.3% of them have year round available food stock and 80.6% of them feed themselves three to four times per a day compared to non adopters households and this also helped them to adapt to climate change, to be food secured, and for this reason, there should be increase in good extension services in the promotion and dissemination of CA technology. This can be achieved by increasing number of extension workers operating in the areas and increase number of demonstrations when introducing CA technology to farmers.

Key Words: Conservation Agriculture, Food Security, Adopters, Non adopters, Climate Change, Adaptation

1.0. INTRODUCTION

1.1. Background of the study

Climate change is considered as posing the greatest challenge to the agriculture and food security in sub-Saharan Africa. This is because the region is vulnerable to climatic change and as coping capacity is perceived to be very low (Nellemann *et al.,* 2009; Shah *et al.,* 2008). Besides that food production, including access to food, in many African countries is projected to be severely compromised by climate variability and change (IPCC, 2007). As a result of the changing climate, areas suitable for agriculture would be negatively affected and the yielding potentially of the many profitable crops produced in the regions, particularly, along the margins of semi-arid, arid and coastal areas are expected to decrease. Climate change would further adversely affect food security and exacerbate malnutrition in the region (Benedict *et al*., 2011).

In the semi-arid regions of sub-Saharan Africa including Ethiopia, short intense storms coupled with prolonged dry spells and poor soil management systems make crop production difficult (Rockstrom, 2000). According to Rockstrom (2000), intensive rainfall causes a high proportion of surface runoff that also carries away the top fertile soil. The climate of Ethiopia is characterized by showing high variability annually, seasonally and geographically. 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 (Evangelista *et al.,* 2013; Tadege, 2007).

Increasing temperature and higher variability in rainfall will influence Ethiopia's agriculture and is expected to worsen the existing conditions, which could lead to further increase of land degradation, soil erosion, deforestation, loss of biodiversity and desertification (Bewket and Conway, 2007). During the last four decades the country has experienced countless localized drought events and several devastating famines, and as a result Ethiopia has been categorized as food-insecure country since the early 1970s (Belay and Abebaw, 2004).

Improving smallholder agricultural systems is a key response to both climate change and food insecurity (McCarthy *et al.,* 2011). In most sub-Saharan countries, agriculture is predominantly operated by poor smallholder farmers and severely constrained by land degradation, promoting sustainable farming practices at plot level has been considered as a strategy to increase agricultural production and productivity (Mohammed *et al.,* 2015). As the key economic sector of most low income countries, improving the resilience of the agricultural system is essential for climate change adaptation (Conant, 2009; Parry *et al.,* 2007, Adger *et al.,* 2003). Improvement in agricultural production systems offers the potentials to provide a significant source of climate change mitigation by increasing carbon stock in terrestrial systems as well as emissions reduction through increased efficiency (FAO, 2009; Paustian *et al.,* 2009; Smith *et al.,* 2008). This can be achieved by promoting conservation agriculture (CA), which consisting of disturbing the soil as little as possible, keeping the soil covered, and mixing and rotating crops, has been discussed to be a potential remedy to soil degradation (Bayala *et al.,* 2012; Rusinamhodzi *et al.,* 2011; Giller *et al.,* 2011).

Conservation agriculture defined as the simultaneous application of minimal soil disturbance, permanent soil cover through a surface mulch of crop residues or living plants, and crop rotations (FAO, 2015). Climate change adaptation in the conservation agriculture techniques are defined in this study as “mulch farming”, “conservation tillage”, “cover cropping”, and “recycling of bio-solids” (FAO, 2008).Conservation agriculture promotes climate change mitigation by enhancing carbon sequestration in the soil and has a huge potential to reverse the net carbon flows from the atmosphere to the biosphere (Marland *et al.,* 2007; Dick *et al.,* 1998). Through eliminating tillage and retaining crop residues and cover crops where they lie for decomposition CA enhances climate change mitigation by slowing down carbon loss and can eventually reverse it (Baker *et al.,* 2007). In addition to keeping carbon in the soil, no-till farming reduces nitrous oxide (N_2O) emissions, depending on rotation (Hobbs and Govaerts, 2010). This in turn enhances climate change mitigation as it reduces greenhouse gases emission to the atmosphere and offsetting their atmospheric concentrations. Conservation agriculture has been proven to reduce greenhouse gas emissions and enhance their role as carbon sinks (FAO, 2012a). It also promote adaptation through mulch farming, “conservation tillage”, “cover cropping”, and “recycling of bio-solids” (FAO, 2008). The increase in soil moisture as a result of CA application has a potential of enabling crops to deal successfully with a problem of seasonal dry spells, mitigate the effects of drought and rainfall variability and reduce the risk of crop failure (Thierfelder and Wall, 2010), which can be considered as good adaptation strategies to climate change. According to the reports of Thierfelder and Wall (2009), CA has significant potential to improve rainfall-use efficiency through increased water infiltration and decreased evaporation from the soil surface, with associated decreases in runoff and soil erosion. And this in turn enhances adaptation to the impacts of climate change to the smallholder farmers. Benefits of CA systems to climate change adaptation and mitigation have been widely published (Lanckriet *et al.*, 2012; Li *et al.*, 2011; Thierfelder and Wall, 2009, 2010; Govaerts *et al.*, 2009; Kassam *et al.*, 2009). These benefits include less erosion possibilities, better water conservation, improvement in air quality due to less emission being produced, and a chance for larger biodiversity in a given area. As defined by Friedrich *et al.* (2009), CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Hobbs and Govaerts (2010) highlighted CA as a climate change adaptation strategy where improved soil quality and improved nutrient cycling will improve the resilience of crops to adapt to changes in local climate change.

Conservation agriculture emerged in the 1970s mostly in the USA and became an acceptable practice in the USA, Brazil, Argentina, Canada and Australia mainly because of its ability to combat increased soil erosion and land degradation and because of lower fuel costs (Harrington 2008; Dumanskietal, 2006). It was developed and adopted widely by farmers in South America mainly because it significantly reduced soil erosion, decreased labor costs and generally led to higher income and a better standard of living for the farmers (Lahmar, 2010; Ribeiro *et al.*, 2007). It is also a powerful mechanism to adapt to climate change by increasing resilience to drought and increasing water-use efficiency

The CA practices were introduced to Ethiopia in 1998 by Sasakawa Global 2000 (SG 2000) on maize production (Matsumoto *et al.*, 2004). Recently, recognizing its predetermined benefit, government, non-government organizations (NGOs) and private sectors are involved in promotion of CA (Melaku, 2015). Currently, there is also strong interest from Ethiopian Ministry of Agriculture in CA. They have developed the second phase of the Sustainable Land Management Program which encompasses CA as its component (SLMP - 2). SLMP phase II will include the up-scaling of climate resilient farming systems or climate smart agriculture (CSA) that increases productivity and at the same time contributes to climate mitigation. The main focus will be on up-scaling CA and on farm agro forestry systems (ACT, 2013). In an attempt to increase agricultural productivity and improved food security at both national and household levels, efforts have been underway to generate and disseminate improved agricultural technologies among Ethiopian smallholder farmers. Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, 1996).

Loka Abaya district is one of the areas that has promoted CA over the last few years to adapt to climate change, to improve soil fertility, crop productivity and enhance food and nutrition security in the farming communities by active farmers' participatory action and through continues farmers' capacity building in the form of conservation farming by SIMLESA/HARC, FAO and DCG/NCA/HU (Girma and Merga, 2017). Therefore, the aim of this study was to investigate the Perceptions of smallholder farmers on conservation agriculture systems to food security and climate change adaptation in Loka Abaya district, southern Ethiopia.

1.2. Statement of the Problem

In Loka Abaya district, agricultural production is threatened by lack of enough moisture and degradation of land. Climate change impacts such as degradation of natural resources and frequent droughts are causing major agricultural and food security challenges of the area (Bewket *et al.,* 2015). According to the study of (Bewket *et al.,* 2015), the district is one of the semi-arid environments that is continuously being affected by climate change and variability. There is high demand for sustainable food production for rapidly increasing population, mitigating the impacts of climate change and enhancing the adaptation to the systems. This needs the introduction of climate resilient technologies that meet these requirements. Conservation agriculture is one of climate resilient technology, which can enhance sustainable food production, prevent land degradation, soil erosion, and improve soil structure and aeration, greater water retention, under the changing climatic conditions at the same time improving climate change mitigation and adaptation (Blanco and Lal, 2008). Resilience is the system's ability to recover quickly from damage or change for example, a hurricane or pest outbreak (Folke, 2006).

Conservation Agriculture (CA) is being promoted over conventional agriculture so as to improve soil health and sustain long term crop productivity (Govaerts *et al.*, 2009; Hobbs *et al.*, 2008). It revolves around three main principles: minimum soil disturbance; permanent soil cover, primarily by retaining crop residues as mulch; and crop rotation, especially with legumes (FAO, 2009). CA mitigates the impacts of climate change through non-tillage practices in the achieving reduction of soil erosion and run off. The erosion risk decreases as the soil surface is continuously covered mainly during the rainy season. Using radio-isotopic techniques (7Be), Nouira *et al.* (2007) found that, no-tillage systems reduce significantly soil erosion rate and sediment losses as compared to conventional tillage (CT) in semiarid Morocco. Using rainfall simulation technique, Moussadek *et al.* (2011) and Dimanche (1997) concluded that CA maximize the green water component of the hydrological cycle and minimize losses by runoff and evaporation in semiarid areas of Morocco.

For that reason different projects such as Dry Lands Coordination Group /DCG-Norway with Hawassa University and SIMLESA and FAO with Hawassa Agricultural Research Center/HARC/ have been promoting Conservation Agricultural technologies to enhance food and nutritional security, increase crop production and productivity by conserving water and soil in its project targeted areas as a part of the solution for food insecurity situation caused by aforementioned problems of moisture stress and land degradation. The projects provided conservation farming training to farmers, development agents, community development facilitators and project experts, and also demonstrated conservation farming plots in various selected sites. In addition, the projects provided incentives like seeds, herbicides, and fertilizer for the farmers who are willing to adopt the technology. And also HARC and NCA has been promoting conservation farming at Boricha, Halaba and Loka Abaya districts (WAO, 2016).

However, the potentials roles of conservation agriculture in contributing to food security, climate change adaptation in the project implemented districts were not assessed. Motivated by the above gaps, this study was focused on the identification of the Perceptions of Smallholder farmers on the potential roles of conservation agriculture for food security and climate change adaptation at Loka Abaya district.

1.3. Objectives

1.3.1. General objective

The general objective of this study was to examine the perceptions of smallholder farmers on the potential roles of CA for food security and climate change adaptation Loka Abaya district, southern Ethiopia.

1.3.2. Specific Objectives

- To assesses the trends of climate change at the study area;
- To assess the potentials of conservation agriculture in enhancing the adaptation of the smallholder farmers to the impacts of climate change;
- To investigate the role of conservation agriculture in ensuring food security for the smallholder farmers in the study area and
- To assesses the factors affecting the adoption of conservation agriculture technology in the study area.

1.4. Research questions

- What are the trends of climate change at Loka Abaya?
- How conservation agriculture enhance the adaptation of the small scale farmers to the impacts of climate change?
- What are the roles that conservation agriculture has to ensure food security of the small scale farmers at Loka Abaya?
- What are the factors affecting the adoption of conservation agriculture technology in the study area?

1.5. Hypothesis of the study

- Conservation agriculture has potential to contribute food security and climate change adaptation.

1.6. Significance of the study

Understanding and researching on the contribution of conservation agriculture technologies is imperative to speed up technology dissemination and provide required information for developments actors. Specifically, identification of the roles of CA technologies is essential for development practitioners, policy makers and individuals who are directly or indirectly involved in CA planning and designing for large scale implementation at national level. The outputs of this study will be used as an input for development or modification of CA promotion strategies in Ethiopia. More specifically, the information from this study on contribution of conservation agriculture to food security, climate change mitigation and adaptation can be used to:

1. Provide feedback from farmers that are helpful in refining the technology generation effort; assess the effectiveness of a technology transfer strategy;
2. Improve the link and flow of information between research and extension services and
3. Document the role of CA technology generation or extension

2. LITERATURE REVIEW

2.1. Terminologies and Concepts

Conservation Agriculture: is defined as the simultaneous application of minimal soil disturbance, permanent soil cover through a surface mulch of crop residues or living plants, and crop rotations (FAO, 2015).

Tillage: is the mechanical disturbance of the soil (through plowing, cultivation or digging) and has been used by farmers since the first settled agricultural production systems tens of thousands of years ago (Lal, 2009).

Adaptation: refers to the “adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts” More specifically, it refers to “processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate” (IPCC, 2001). Climate change adaptation in the conservation agriculture techniques are defined in this study as “mulch farming”, “conservation tillage”, “cover cropping”, and “recycling of bio-solids” (FAO, 2008).

Adaptive capacity: refers to the potential, capability, or ability of a system to adapt to climate change stimuli or their effects or impacts. Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards (Kates, 2000; Downing *et al.*, 1999; Kelly and Adger, 1999; Mileti, 1999; Bohle *et al.*, 1994).

Mitigation: a human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks ((IPCC, 2008).

“Adaptability,” “resilience,” and the related term “resistance” have the three different descriptors of how a system responds to change.

I). Resistance: -is the tendency of a system to remain stable in the face of external perturbations. For instance, an agro forestry that continues to produce similar yields despite fluctuating rainfall levels would be considered highly resistant.

II). Resilience: - refers to the system's ability to recover quickly from damage or change for example, a hurricane or pest outbreak. While this term has its roots in ecology, its use has now broadened to include the concept of "socio ecological resilience" (Folke, 2006), which encompasses the role of humans in adaptively managing systems to maintain them within a range of bounds that are conducive to human wellbeing (e.g., maintaining minimum crop yields, water availability, or profitability).

Iii). Adaptability: - implies the use of long-term planning and strategic action to address change both before and after it occurs. By comparison, "coping" is a reactionary response to unanticipated change, often conducted in a crisis mode and oriented toward short-term survival (CARE, 2009a).

IV). Vulnerable system: - is one that has little resistance, resilience, or adaptability to external perturbations. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as "the degree, to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

V). Food security:- is situation which exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

2.2. Conservation Agriculture: An Overview

Conservation agriculture originated in the USA in the 1950s and from then until 2007 the USA had the largest area under no-till worldwide (Kassam *et al.,* 2009) while Asian and African countries have begun to take up CA practices only in the last 10-15 years (Friedrich *et al.*, 2009). As defined by Friedrich *et al.,* (2009), CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Hobbs and Govaerts (2010) highlighted CA as a climate change adaptation strategy where improved soil quality and improved nutrient cycling will improve the resilience of crops to adapt to changes in local climate change.

Many researchers concluded that CA is a system approach to sustainable agriculture in Latin America, Asia and Africa (Mrabet *et al.,* 2012; ; Li *et al.,* 2011; Mkoga *et al.,* 2010; Govaerts *et al.,*2009; Chivenge *et al.,* 2007). There is increasing awareness all over the world of the negative effects of conventional agriculture and the need to change conventional agricultural practices (Morris *et al.,* 2010; Baker *et al.,* 2007). The key problem of conventional agriculture faces, especially in the tropics, is the steady decline in soil fertility, which is closely correlated to the duration of soil use (Singh and Malhi, 2006; Clay *et al.*, 1996). This is primarily due to soil erosion and the loss of organic matter associated with conventional tillage practices (Chivenge et al., 2007), which leave the soil bare and unprotected in times of heavy rainfall, wind and heat (Derpsch, 2003). Thus, zero-tillage was born out of a necessity to combat soil degradation and has been widely adopted by farmers at different scale (Kassam *et al.,* 2009).

Conservation agriculture is a method of managing agro ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resources base and the environment (Corsi *et a.l,* 2012). It is being advocated over conventional agriculture so as to enhance soil health and sustain long term crop productivity (Govaerts *et al.,* 2009; Hobbs *et al.,* 2008). It is conventionally and perhaps most commonly defined as a set of field-level agronomic practices encompassed by three principles.

2.3 Principles of Conservation Agriculture

2.3.1. Minimizing soil disturbance

This can be achieved through direct seeding, minimal or no tillage, and avoidance of excessive compaction by machinery, draft animals, or humans. The aim of this is to enhance a better cohesion between soil aggregates, decrease soil organic matter mineralization and allow the development of soil biota. While no tillage is considered as the ideal, in many cases, however, farmers use reduced tillage, especially when they start to shift towards the practice of CA (Lahmar *et al.*, 2006).

2.3.2. Maintaining permanent soil cover

This is also achieved through the use of cover crops, intercrops, and/or mulching provided by crop residues or other organic matter sources. Under CA, crop residues or cover crops should be maintained on the soil surface as dead or alive mulch. The objective is to protect the soil against weather aggressions and water erosion, to maintain soil moisture (Lal, 1997), to suppress weed growth and to provide shelter and food for the soil biota (Blanchart *et al.*, 2006).

2.3.3. Diversifying crop rotations

This involves the plant context-appropriate sequences of crops often including nitrogen fixing species that help maintain soil health while reducing pest and disease problems. According to Calegari (2001), the use of crop rotations or intercropping is considered essential in CA systems as it offers an option for pest/ weed management that is no longer realized through soil tillage.

Underlying all of these CA principles and practices is the notion that agriculture should nourish and enhance the natural biological processes that support soil fertility, nutrient cycling, and hydrological cycling. These ecosystem services, in turn, benefit farmers by boosting crop yield, reducing the need for external inputs, increasing farm profitability, and reversing land degradation. CA is thus closely aligned with the concept of agro-ecology, in which farms are deliberately managed to foster beneficial ecological processes and disrupt detrimental ones (Milder *et al.*, 2011).

As Milder et al. (2011) stated that, conservation agriculture is often presented as an alternative to conventional Green Revolution style agricultural intensification. It is important, however, not to misunderstand the nature of this distinction. First, CA does not represent the lack of agricultural intensification, but rather intensification along a different pathway, based on agro ecological management of soil, water, nutrients, plants, and animals. Second, the success of both CA and conventional agricultural intensification typically depend on a largely overlapping set of good agronomic practices, including:

- selection of context-appropriate, high-yielding seed varieties;
- optimal and accurately-applied seed spacing and seed density;
- precise and judicious application of fertilizers (whether organic or inorganic) in the optimal locations and quantities;
- context-appropriate crop rotations designed to break pest and disease cycles and prevent the exhaustion of soil nutrients; and
- Introduction of new agricultural technologies through culturally appropriate, participatory means of communication, education, and training.

2.2.3. Environmental implications of conventional versus conservation agriculture

Conventional agriculture through conventional tillage has been asserted to lead to land degradation resulting from common, but exploitative, farming practices such as ploughing that destroys the soil structure and degrades organic matter, burning or removing crop residues, mono cropping among others (Rusinamhodzi *et al.,* 2011). This, in addition to the emissions from the farm equipment itself, increases carbon dioxide levels in the atmosphere (Chivenge *et al.,* 2007). By eliminating tillage, crop residues decompose where they lie, and cover crops, carbon loss can be slowed and eventually reversed (Baker *et al.,* 2007). So that we need to plough through direct seeding, minimal or no tillage, and avoidance of excessive compaction by machinery, draft animals, or humans.

According to Hobbs and Govaerts (2010), agriculture contributes significantly to greenhouse gas (GHG) emissions: CO_2, CH_4 and N_2O for that reason promoting agricultural practices that mitigate climate change by reducing GHG emissions is important. In addition to keeping carbon in the soil, no-till farming reduces nitrous oxide (N_2O) emissions, depending on rotation (Hobbs and Govaerts, 2010). Nitrous oxide is a potent greenhouse gas that stays in the atmosphere for 120 years. Hobbs and Govaerts (2010) illustrated that, no-till has carbon sequestration potential and Govaerts, 2010). Nitrous oxide is a potent greenhouse gas that stays in the atmosphere for 120 years. Hobbs and Govaerts (2010) illustrated that, no-till has carbon sequestration potential through storage of soil organic matter in the soil of crop fields. By the same author, cropland soils are ideal for use as a carbon sink, since they have been depleted of carbon in most areas. It is estimated that enormous carbon that was trapped in the soil has been released because of tillage (Six *et al.,* 2004; Balesdent *et al.*, 2000; Håkansson; 1994). Conventional farming practices that rely on tillage have removed carbon from the soil ecosystem by removing crop residues such as left over corn stalks, and through the addition of chemical fertilizers which have negative effects on soil microbes (Baker *et al.*, 2007).

Conservation agriculture gives farmers a means of conserving, improving and making more efficient use of their natural resources. It is also key to managing agricultural resources for biodiversity preservation as far as agricultural practices have impact on a wide range of ecosystem services, including water quality, pollination, nutrient cycling, soil retention, carbon sequestration, and biodiversity conservation. In turn, ecosystem services affect agricultural productivity (Tscharntke et al. 2005, Varela, 2001).

2.2.4. Role of conservation agriculture for soil quality improvement

Soil organic matter (SOM) is an important determinant of soil fertility, productivity and sustainability, and is a useful indicator of soil quality in tropical condition (Chivenge *et al.*, 2007). According to Chivenge *et al.* (2007), residue retention and reduced tillage are both CA management options that may improve soil organic carbon (SOC) stabilization in tropical soils. In extremely degraded soils there is low recycling of nutrients during the decomposition of organic matter, and low biological activity (small quantity of microorganisms). CA aims to address the problems of soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil (Giller *et al.*, 2009). According to Araya *et al*.

(2012) no-till improves soil quality (soil function), carbon, organic matter, aggregates, protecting the soil from erosion, evaporation of water, and structural breakdown. A reduction in tillage passes helps prevent the compaction of soil. Recently, researchers found that no-till farming makes soil much more stable than ploughed soil (Li *et al.*, 2011). In addition, no-till stores more carbon in the soil and carbon in the form of organic matter is a key factor in holding soil particles together. Crop residues left intact help both natural precipitation and irrigation water infiltrate the soil where it can be used (Friedrich *et al.*, 2009). The crop residue left on the soil surface also limits evaporation, conserving water for plant growth (Thierfelder and Wall, 2009). Soil compaction and no tillage-pan, soil absorbs more water and plants are able to grow their roots deeper into the soil and suck up more water.

2.2.5. Conservation Agriculture Adoption in Worldwide and in Africa

Derpsch and Colleagues (2010) estimated that no-till agriculture (which they equate with CA) was practiced on nearly 116 million ha in 2009, and is increasing at a rate of six million ha per year. Kassam and colleagues (2009) distinguish no-till agriculture from CA (which they define as involving no-till or minimal tillage plus permanent soil cover and diversified crop rotations), and estimate that CA was used on 106 million ha worldwide in 2009. Africa has by far the lowest portion of area under CA or no-till farming, accounting for only about 0.3% of the world total. CA adoption rates vary widely by country in Africa.

CA is a growing movement in eastern and southern Africa, with numerous activities and promotion programs by government agencies and civil society alike. For example, FAO (2010c) reports that twelve countries have identified CA Focal Points to promote and coordinate CA activities (Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe). Most of these countries have established multi-stakeholder task forces that include the CA agenda. While CA is also practiced in other parts of Africa (e.g. Burkina Faso, Morocco, Niger, and Tunisia), promotion and adoption tend to be limited. CA in Ghana is significant, but stagnated after donor funding and promotion ended.
The rate of adoption varies according to farm size, with large commercial farms comprising most of the area under CA globally and in parts of Africa. In eastern and southern Africa, CA has been

adopted by many large commercial operators, but the extent of adoption among smallholders is not well documented in most countries and, with a few exceptions, is estimated to be very low.

According to Baudron et al. (2009), CA adoption often relies on a donor project or combination of "push" and "pull" factors to motivate a change from the current situation. Pull factors are for example, farmers may turn to CA when the knowledge and resources to do so are adequate and appealing and push factors are when a crisis or set of substantially new conditions requires response, which may include high food prices, food insecurity, natural disasters, environmental regulation, rising input and energy costs, or climate change. Mazvimavi and Twomlow (2009) illustrated that, vulnerable smallholders in Africa are particularly unlikely to adopt CA spontaneously, but there is some evidence those farmers who have lower risks have adopted CA without external incentives, especially by learning from neighbors (See figure 1).

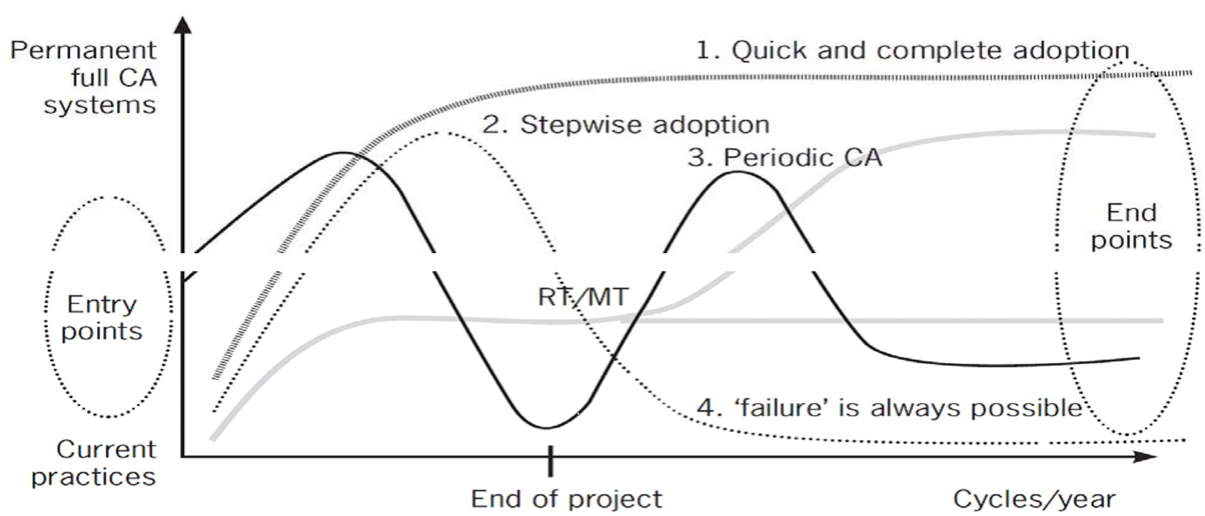


Figure 1: Adaption path way of CA technology in Africa and other world (Baudron *et al.*, 2007)

According to Baudron et al. (2007) from the above figure, there are four adoption pathways: 1) quick and complete adoption of CA as recommended; 2) stepwise adoption of CA practices, which may or may not lead to complete adoption over time (RT =reduced tillage, MT = minimum tillage); 3) CA practiced during some farming cycles but not others; and 4) use of CA practices stops soon after the end of the project, perhaps because incentives are no longer provided.

2.2.6. Evidence on Key Outcomes of CA

There are empirical evidences on the effects of CA management on five key outcome dimensions: crop yields, farm profitability, labor demand and supply, gender dimensions, and conservation of biodiversity and ecosystem services (Milder *et al.*, 2011), and each of the evidences are tried to describe in the following ways:

2.2.6.1. Crop yield

Various studies have been conducted to compare the yields of CA systems to those of conventional farming systems. For instance, Kassam et al. (2009) and Derpsch et al. (2010) in Latin America, Africa, and Asia have concluded that, CA yields are approximately 20-120% higher than those in conventional agriculture. In Africa, numerous studies have also documented yield increases associated with a shift to CA practices across a range of geographies and crops. For instance,

- Kaumbutho and Kienzle (2007) found that in the Laikipia district in Kenya yields in maize, wheat, potato, and bean were 50-200% higher in CA than in conventional systems.
- Boahen et al. (2007) reported that maize yields in Ghana were up to three times higher with CA than in traditional slash-and-burn systems.
- According to Shetto et al. (2007), yields increased by 93-360% in maize and sunflower CA systems in Tanzania following adoption of conservation tillage (ripping) and a mucuna cover crop.
- In Uganda, conventional systems have a grain yield of about 2,500 kg ha^{-1}, but yields increase to 3,000-3,100 kg ha^{-1} under different CA methods (Nyende et al., 2007).
- FAO (2010b) also found significant yield increases in Zimbabwe across several crops, including maize, sorghum, millet, cowpea, and soybean.
- When examining CA yields in Malawi, Mloza-Banda and Nanthambwe (2010) found that maize grain yields from CA were between 294% and 477% higher than yields in

traditional systems in 2000/2001 and 394% to 609% higher in 2001/2002 across six different Agricultural Development Divisions.

- In Zambia, yields on farms using CA practices doubled in maize plots and were 60% higher for cotton, as compared to conventional plowing systems (Haggblade and Tembo, 2003).
- Based on a meta-analysis of 94 peer-reviewed publications from all regions of sub-Saharan Africa, Sileshi and colleagues (2008) determined that maize yields increased significantly through the use of rotations or intercropping with woody or herbaceous legumes (which are commonly a component of African CA). Yield increases averaged 1.6 t ha^{-1} for coppiced woody legumes, 1.3 t ha^{-1} for non-coppiced woody legumes, and 0.8 t/ha for herbaceous green manure legumes.

CA can improve yields in Sub-Saharan Africa, and these often work in synergy. Mulching and residue management can increase soil fertility and nutrient availability to plants, which is one of the best ways to boost production of nutrient-hungry crops such as maize. Improved water availability throughout the cropping cycle is another key mechanism. Also important in seasonally dry climates is the ability to seed crops immediately after the rains begins, thus accelerating the crop growth cycle and maximizing utilization of rainfall during a short rainy season (FAO, 2010d). Complementary practices such as the use of context-appropriate high-yielding seeds, appropriate seed spacing and densities, use of inorganic and/or organic fertilizers, and improved pest management practices can increase the yield gains associated with improved soil, residue, and water management.

2.2.6.2. Profitability

Based on the several studies from sub-Saharan Africa, the profitability of CA is almost always higher than that of conventional agriculture, For example:

- A FAO (2010a) budget analysis in Zambia and Zimbabwe demonstrated that returns under CA are significantly higher than under conventional systems. In Zambia, annual returns were US\$104 ha^{-1} under CA and US\$19 ha^{-1} under conventional tillage. In

Zimbabwe, returns were US$213 ha^{-1} under CA and US$61 ha^{-1} under a conventional system.

- According to Shetto and Owenya (2007), net benefits in Tanzania maize systems were found to be 34,500 Tanzanian shillings (TZS) per ha on conventional farms versus 213,050 TZS ha^{-1} on farms practicing CA. These figures were 89,350 TZS ha^{-1} versus 416,450 TZS ha^{-1} for sunflower. This analysis took into account weeding, labor, fertilizer, and implement costs.

According to FAO (2008) and Derpsch et al. (2010), the increased profitability of CA tends to be a result of higher yields, lower expenditures on energy and other inputs, and sometimes a reduction in labor costs. In addition to labor, the major costs associated with CA are for equipment, seeds, and herbicides. In the long-term, CA equipment tends to be less expensive than equipment for conventional agriculture because it lasts longer, is less expensive to maintain and repair, and consumes less fuel (for power operated machinery) (Apina, 2009). CA can reduce the cost of mechanization by 50% relative to conventional agriculture (Friedrich and colleagues, 2009). Similarly, CA typically reduces the cost of purchased fertilizer by substituting nitrogen-fixing plants and improved soil biological processes as indigenous sources of soil fertility.

2.2.6.3. Labor

Even though CA requires deep-digging to penetrate soil crusts a task that is very arduous and may increase the initial labor requirement for land preparation, land preparation in CA requires less labor than in conventional agriculture since whole-field plowing or tillage is not required. In the long-term, CA very often reduces the labor required for farming, relative to conventional practice, although this is not universally the case. In the short-term, it is quite common for CA to require increased labor, especially for weeding and land preparation. Tillage is an efficient way to control weeds, but with reduced tillage, weeding can require substantial initial increases in labor if herbicides are not used. Unexpected labor peaks can also occur at harvest time due to increased yields from CA (Milder *et al.*, 2011).

2.2.6.4. Gender Dimensions

CA can preferentially benefit women. According to Boahen *et al.* (2007), in Ghana, for example, the most time consuming activities in conventional agriculture are uprooting grass and de-stumping. As these tasks are mostly done by women and children, a transition to CA was found to increase the time available for other household activities, since these weeds will be controlled by herbicides. Similarly, in Zambia, a switch to CA allowed women and children to carry out lighter and more diversified tasks (Baudron et al., 2007). For female-headed households that have little or no access to plows or plowing services, CA may be a more feasible option since land can be prepared through ripping, and seeding can be accomplished with jab planters, which are portable and easy for women to operate (Shetto and Owenya, 2007; Kaumbutho and Kienzle, 2007).

Since CA reduces the overall time required for farming, it can allow women to diversify their activities by participating in off-farm income-generating activities (FAO 2010d; Baudron *et al.*, 2007). According to Baudron et al. (2007), lower labor requirements can be a significant advantage for women who are both farmers and caretakers. Reduced work hours, less heavy farm work, and lower stress associated with CA are all valued highly by women.

2.2.6.5. Biodiversity and Ecosystem Services

According to Jeffery *et al*. (2011), conservation agriculture to be likely to have three positive broad categories of impacts on the conservation of biodiversity and ecosystem services; first, it has direct impacts on plot- and farm-scale ecosystem services, which are knowingly managed as part of CA practice. Second, CA has indirect effects on further ecosystem services as well as connected biodiversity within and around cultivated areas at the farm and community scale. Third, CA has indirect effects on biodiversity and ecosystem conservation at the community, landscape, and even larger scales.

Two basic ecosystem services that support agricultural productivity, such as management of soil fertility and hydrological cycling, are necessary part of CA. Many researchers have been conducted on these potential benefits in Sub-Saharan Africa and other parts of the world. In terms of soil fertility, the improved soil structure resulting from CA enhances aeration and other conditions required for efficient nutrient cycling. For instance, Hobbs et al. (2008) and Kassam et al. (2009) stated that soil organic matter has been found to increase significantly over time in CA systems, primarily due to the introduction of additional organic matter as crop residues or mulch and to the reduction or elimination of tillage, which tends to speed the oxidation of soil organic matter. Non-tillage systems are also associated with increased levels of available phosphorus in the upper soil layer (e.g., 0-5 cm), apparently due largely to the role of biological processes in phosphorus cycling (Verhulst et al., 2010). In established CA systems, most nutrients are concentrated and maintained in the top 10 cm of the soil, where they are readily available to plants (Kassam et al., 2009). Soil fertility also benefits from reduced rates of erosion in CA systems (Reicosky and Saxton, 2007).

CA has potentially beneficial effects on water management and water use efficiency. Reicosky and Saxton (2007) estimated that, with an increase in soil organic matter and root density under CA, water infiltration and water holding capacity are enhanced, making water more accessible throughout the farming cycle. For each percent increase in soil organic matter, an additional 150 $m3/ha^{-1}$ of water can be stored in the soil (Friedrich, 2008). Surface mulches and improved soil pore structure also increase infiltration and absorption capacity, while reducing evaporation. These benefits help reduce the risk of erosion and flooding during heavy rains, contribute to aquifer recharge, and make more water available to crops (Verhulst *et al.*,2010;Derpsch, 2008;Hobbs, 2007;). Taken together, these characteristics increase crops' resistance to drought and tend to reduce yield variations between dry and wet years relate to conventional farming practice.

2.3. Roles of Conservation Agriculture for Climate Change Adaptation and Mitigation Strategies

2.3.1. Roles of conservation agriculture for climate change adaptation

Agricultural production, including access to food in many African countries, is projected to become severely compromised by climate change (Below *et al.,* 2010). Recent projections suggest that climate change could significantly reduce crop yields and increase yield variability in many regions of the world within a decade or two, including 20-35% decreases in maize yields in southern Africa by 2030 (Lobell *et al.,* 2008). This arises from the fact that African agriculture is mainly rain-fed, and the areas suitable for agriculture, the length of growing seasons and yield potential, particularly along the arid and semi arid areas, are all expected to decrease. Therefore, adaptation is a key factor that will shape the future severity of climate change impacts on food production (Lobell *et al.,* 2008). Benefits of CA systems to climate change adaptation and mitigation have been widely published (Lanckriet *et al.,* 2012; Li *et al.*, 2011 Thierfelder and Wall, 2009, 2010; Govaerts *et al.,* 2009; Kassam *et al.,* 2009). These benefits include less erosion possibilities, better water conservation, improvement in air quality due to less emission being produced, and a chance for larger biodiversity in a given area. Producers will find that the benefits of CA will come later rather than sooner (Thierfelder and Wall, 2009; Chivenge *et al.,* 2007) since CA takes time to build up enough organic matter and have soils become their own fertilizer, the process does not start to work over night. But if producers make it through the first few years of production, results will start to become more satisfactory.

Improved soil quality and improved nutrient cycling with CA will improve the resilience of crops to adapt to changes in local climate change while drought tolerance can be increased in some areas with CA (Hobbs and Govaerts, 2010). Thierfelder and Wall (2009) concluded that CA benefits more in areas where soil moisture is a limiting factor like in Bugesera district (Eastern Rwanda). Hobbs and Govaerts (2010) highlighted CA as a Climate Change Adaptation strategy where improved soil quality and improved nutrient cycling will improve the resilience of crops to adapt to changes in local climate change.

Reduced vulnerability to effects of drought, less erosion, and lesser extremes of soil temperatures represent a managed adaptation of CA systems to climate change effects such as, for example, more intense rainstorms, increased daily ranges of temperatures, and more severe periods of drought. Overall, CA systems have a higher adaptability to climate change because of the higher effective rainfall due to higher infiltration and therefore minimum flooding and soil erosion as well as greater soil moisture-holding capacity. Derpsch et al. (1991), illustrated that the advantage of CA over CT in terms of the greater soil moisture-holding capacity and therefore duration of plant-available soil moisture is and also he show that soil moisture conditions in rooting zones through growing seasons under CA are better than under both minimum and conventional tillage. Thus crops under CA systems can continue towards maturity for longer than those under conventional tillage. In addition, the period in which available nutrients can be taken up by plants is extended, increasing the efficiency of use.

The greater volume and longer duration of soil moisture's availability to plants (between the soil's field capacity and wilting point) has significant positive outcomes both for farming stability and profitability. The range of pore sizes which achieves this also implies the presence of larger pores which contribute to through-flow of incident rainwater down to the groundwater (Shaxson et al., 2008). FAO, (2012a) reported a case study on Zambia by Samuel Bells showed that combining conservation agriculture with tree cultivation increases crop yields by 240–400 percent enhances soil carbon sequestration and improves resilience to climate shocks. In addition, the biomass that is produced can be used for feeding livestock. In Mexico, a study carried out by the International Maize and Wheat Improvement Center (CYMMIT) compared two different cropping systems and found that conservation agriculture produced the highest yield in both environments. In most cases, soil organic carbon increased with conservation agriculture, while in others it remained the same. However, it was demonstrated that combining zero tillage with the removal or burning of cover crops was an unsustainable approach that did not improve yields nor increase soil carbon (FAO, 2012a).

2.3.2. Roles of CA for mitigating Climate change

Conservation agriculture mitigates climate change through balancing the greenhouse concentration by reducing the emissions or sequestering significant net amounts of carbon. According to the Intergovernmental Panel on Climate Change (IPCC), agriculture, deforestation, and land-use change together account for about 31% of total global anthropogenic GHG emissions. As agriculture and land use change has significant capacity to exacerbate GHG emissions and climate change; it also holds major potential to mitigate these impacts. The mitigation potential from agriculture (i.e., the biophysical capacity to mitigate GHG emissions) is estimated to be 5,500-6,000 million tons of CO_2-equivalent per year (Mt CO_2-eq yr^{-1}) by 2030 (Smith *et al.*, 2007).

The economically feasible mitigation potentials are estimated to be 1,500-1,600, 2,500- 2,700, and 4,000-4,300 Mt CO_2-eq yr^{-1} at carbon prices of $20, $50 and $100 /t CO_2-eq, respectively. About 70% of this mitigation potential lies in developing countries. Sub-Saharan Africa's mitigation potential from agriculture is relatively high, at about 924 Mt CO_2-eq yr^{-1} by 2030, compared to 707 Mt CO_2-eq yr^{-1} for all of South America and 374 Mt CO_2-eq yr^{-1} for North America (Smith *et al.*,2007). Within agricultural systems, there are several options for mitigating climate change, including both the reduction of existing or potential emissions and the net sequestration of CO_2 to offset emissions elsewhere. The greatest potential mitigation opportunities include:

I). *Reduction in CO_2 emissions* associated with a wide variety of practices, including deforestation for agriculture and oxidation of soil carbon;

II). *Net sequestration of CO_2 in agro ecosystems*, including in soils and trees;

According to the IPCC, soil carbon sequestration offers by far the most important potential for agricultural GHG mitigation, with an estimated 89% of the total technical potential worldwide (Smith *et al.*, 2007). Similar to agriculture in general, CA can help mitigate atmospheric GHG by: 1) reducing existing emissions sources, and 2) sequestering net carbon. Baker and Colleagues (2007) estimated that the conversion of all croplands to conservation tillage globally could sequester 25 GtC over the next 50 years. This is equivalent to 1,833 Mt CO_2-eq yr^{-1}, making conservation tillage among the most significant opportunities from all sectors (not just agriculture) for stabilizing global GHG concentrations.

Figure 4 is a visual heuristic for comparing the order-of-magnitude C sequestration potential of various CA components, including both site and landscape management practices and both belowground and aboveground carbon pools. It is important to note that since the ranges of recorded GHG mitigation values for many of these practices is quite wide; the relative size of these mitigation benefits could shift considerably in specific situations.

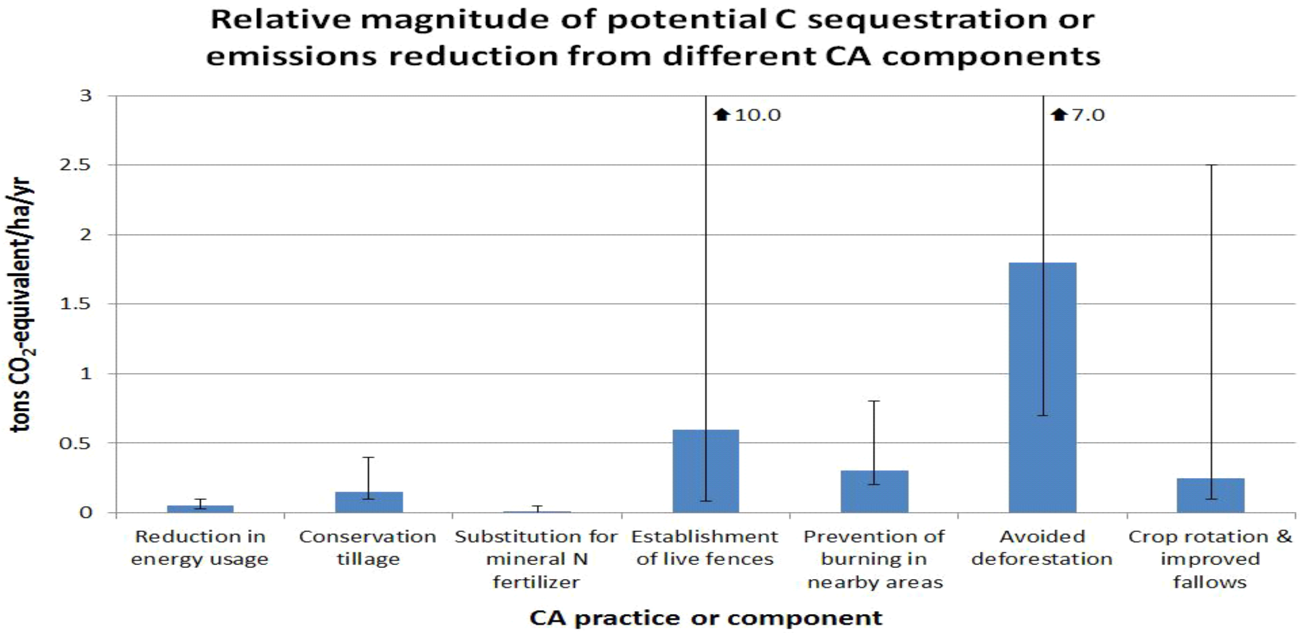


Figure 2: CA practice or components (Source: Milder et al., 2011).

The relative size of bars on this graph are mid-range estimates based on a synthesis of the literature on the GHG mitigation potential of each practice in semi-arid to semi-humid environments in Sub-Saharan Africa.

2.3.2.1 .Evidence on CA, GHG Emissions, and Carbon Sequestration

CA can help mitigate atmospheric GHG by: 1) reducing existing emissions sources, and 2) sequestering net carbon. Baker and Colleagues (2007) estimated that the conversion of all croplands to conservation tillage globally could sequester 25 Gt C over the next 50 years. This is equivalent to 1,833 Mt CO2-eq yr^{-1}, making conservation tillage among the most significant opportunities from all sectors (not just agriculture) for stabilizing global GHG concentrations.

2.4. Basic challenges and Opportunities for CA

2.4.1. Opportunities for CA in Africa

2.4.1.1. Agro ecological and Climatic Suitability

CA is applicable across diverse geographic regions, agro ecological zones, soil types, plot sizes, and crops throughout Africa (Derpsch et al., 2010; FAO, 2010a). Thiombiano and Meshack (2009) examined the biophysical conditions particularly related to the availability of water and biomass that would allow for CA in different parts of Africa. Sub-humid zones were found to have the best potential for CA, and deserts were the only type of ecosystem not suitable for CA due to insufficient biomass production. In arid and semi-arid zones, reduced tillage and direct seeding are needed to minimize water loss, promote timely planting, and make use of scarce rainfall. Studies by the Regional Land Management Unit (RELMA, 2007) found that in conditions of limited water availability CA should focus on water harvesting and water use efficiency. In these settings, less emphasis should be placed on soil cover maintenance, and fertilizers should be used to counteract soil nutrient depletion. Increases in biomass production over time can lead to greater soil cover, allowing for more organic matter and improved water holding capacity in soils. In semi-arid zones, options for cover crops and crop residues for soil cover increase with higher humidity levels. Cover crops are a useful starting point in sub-humid zones as well, and can result in better mulch, higher yields, and reduced weed pressure. Agro forestry systems, such as ICRAF's Evergreen Agriculture, are examples of systems that add soil cover in semi-arid and arid environments.

2.4.2. Challenges for Conservation Agriculture

According to Baudron et al. (2007), key constraints to CA adoption in Africa are well-known, and include biophysical constraints (e.g., climate), knowledge constraints, input constraints, financial constraints, and structural constraints (e.g., government policy, investment priorities, and land tenure systems), It is difficult to generalize about the relative importance of these different constraints because such data have not been standardized across diverse settings.

2.4.2.1. Knowledge Constraints

Derpsch (2008b) illustrated that, adopting CA requires substantial changes not only in practices, but also in mindset. CA contradicts much of conventional farming knowledge and farming traditions. Many farmers are accustomed to thinking of the plow or the hoe as an essential part of agriculture, and may find it difficult to overcome the idea that plowing is not required for successful planting. It can be particularly difficult to convince farmers to adopt CA if they do not experience strong environmental or economic pressures to change.

Conventional agricultural practices may also be tightly woven into local culture and ritual, making such practices even more entrenched. While farmers that practice CA tend to have a positive view of it (Friedrich and Kassam, 2009), a lack of experiential knowledge hinders adoption. As with agriculture in general, CA is a knowledge intensive process that requires substantial planning, intuition, and a willingness to experiment and learn. However, the knowledge base for CA is substantially different from that for conventional agriculture. For instance, the recommended approaches to remedying soil compaction differ considerably between conventional agriculture and CA, as do methods for seeding, fertilization, erosion control, residue management, and water management.

Although some countries have incorporated CA into their extension programs, others actively promote conventional farming techniques that are at odds with CA. Even where CA is taught, this education is often not well integrated with land management systems at the local level. For instance, CA may be demonstrated in plots at experiment stations, but not in farmers' fields where it is more likely to lead to smallholder adoption (Baudron *et al.,* 2009).

2.4.2.2. Input constraints

Access to equipment, seeds, fertilizers, and herbicides is a significant constraint to scaling up CA in Africa. According to Milder et al., (2011), limited access to (or affordability of) inorganic fertilizers, pesticides, and herbicides may also represent a constraint to practicing CA in a maximally productive manner. However, one of the chief advantages of CA is that it can increase yields in contexts where agrochemicals are not available or not affordable, by fostering biological processes and management practices that enhance soil fertility, pest control, and weed control. A final input constraint that tends to be more severe in CA than in conventional agriculture is the availability of biomass for mulches or organic fertilizer. Although soil nutrients and soil cover in CA can often be provided mainly by cover crops or intercrops, some exogenous organic matter may be needed to provide supplemental fertilizer and soil cover. Non-edible biomass in farm fields and the surrounding field margins, fallows, and forests is often in high demand for livestock fodder, firewood, building material, and other uses. In places where the population density is relatively low or rainfall is moderate to high, biomass is rarely a major constraint. However, this constraint can become severe in semi-arid regions with high population density.

2.4.2.3. Financial constraints

According to Hobbs (2007), CA is generally more profitable in the long-term than conventional farming. However, achieving these long-term benefits may require initial investment, which is often prohibitively expensive or risky for small farmers to undertake on their own. Vulnerable farmers are especially risk averse due to household food security concerns, and there is little room for error. In addition, while many farmers reap benefits in the first year of practicing CA, others do not realize increased yields or profitability for 3-7 years.

2.4.2.4. Policy, Investment, and Land Tenure Constraints

Structural constraints to CA include unsupportive policy environments, extension and education systems, incentive structures, donor investment priorities, and land tenure systems. Conventional farming methods are deeply entrenched in many African countries, from the local level (where the farming cycle is commonly embedded in village tradition and ritual) to the national level (where research, education, and training rarely have a strong CA component). Even in countries where many farmers are practicing CA, there is often little awareness of CA among policy makers, and in some cases existing policies work against CA (Thiombiano and Meshack, 2009).

2.5. Basic Aspects of Food security

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996)**.** According to WHO definition , food security is situation when all people at all times have both physical and economic access to enough food for an active, healthy life; the ways in which food is produced and distributed are respectful of the natural processes of the earth and thus sustainable;

From these definitions, achieving food security seems utopian (at least ideal) and no country could hope to reach in reality. Therefore, for specific program/project or particular nation definition of food security should be something achievable or measurable at least for certain duration. But, these definitions should cover the basics.

2.5.1. Household Food Security

A household is food secure when it has access to the food needed for a healthy life for all its members (adequate in terms of quality, quantity, and safety and culturally acceptable) and when it is not at undue risk of losing such access.

2.5.2. Dimensions of Food Security

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

Food availability

This dimension addresses supply side of the food security and expects sufficient quantities of quality food from domestic agriculture production or import. This is simple mathematical calculation weather the food available in certain territory/country is enough to feed the total population in that particular territory and calculated from the level of local agriculture production at that territory, stock levels and net import/export.

Food Access

Food access is another dimension of food security which encompasses income, expenditure and buying capacity of households or individuals. Food access addresses whether the households or individuals have enough resources to acquire appropriate quantity of quality foods. Some of the indicators of this dimension at different levels are food price, wage rate, per capita food consumption, meal frequency, employment rate etc.

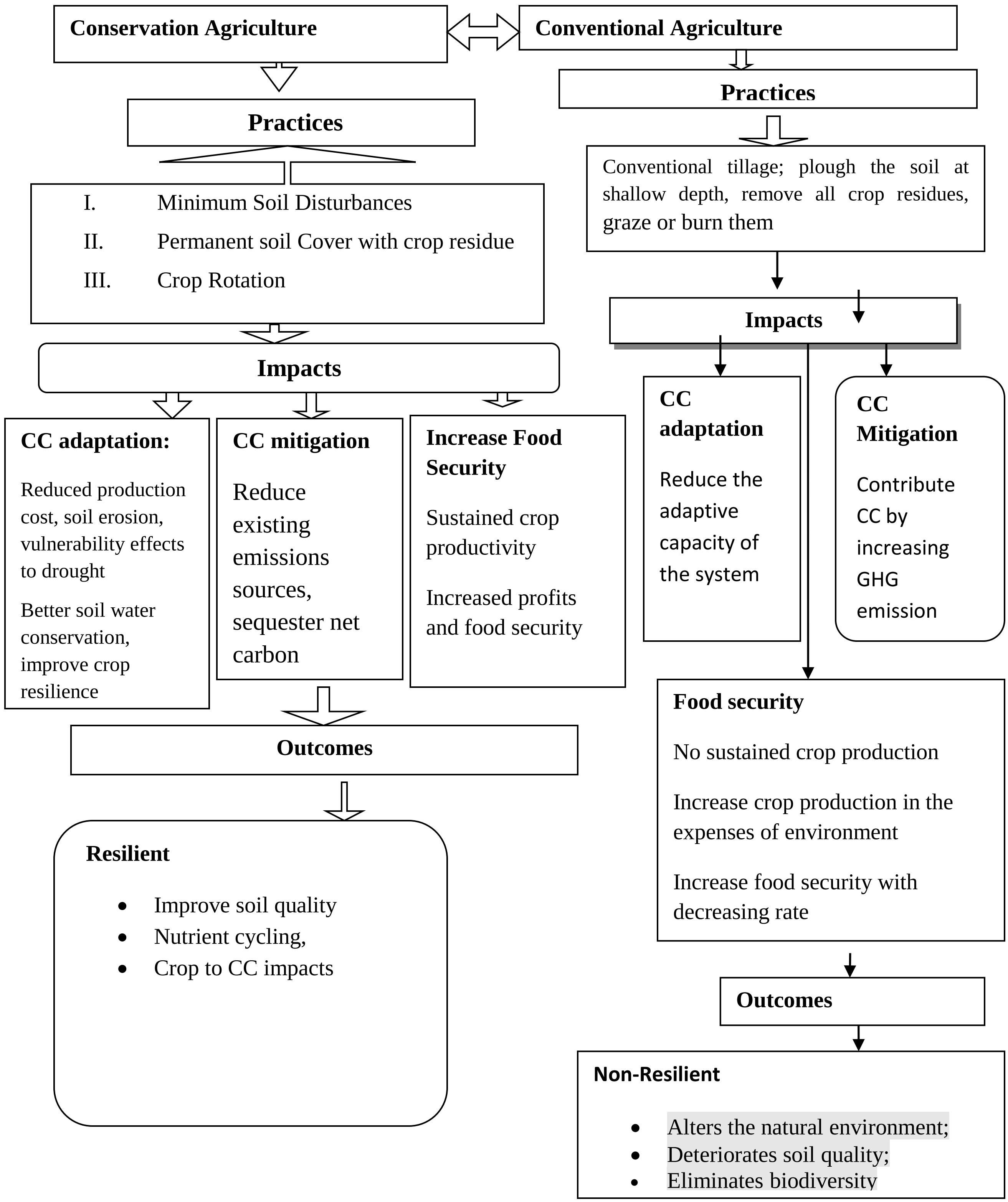
Food utilization

Food utilization is another dimension of food security which addresses not only how much food the people eat but also what and how they eat. It also covers the food preparation, intra-household food distribution, water and sanitation and health care practices.

Stability

This dimension addresses the stability of the other three dimensions over time. People cannot be considered food secure until they feel so and they do not feel food secure until there is stability of availability, accessibility and proper utilization condition.

Figure 3: Conceptual Framework of the Study

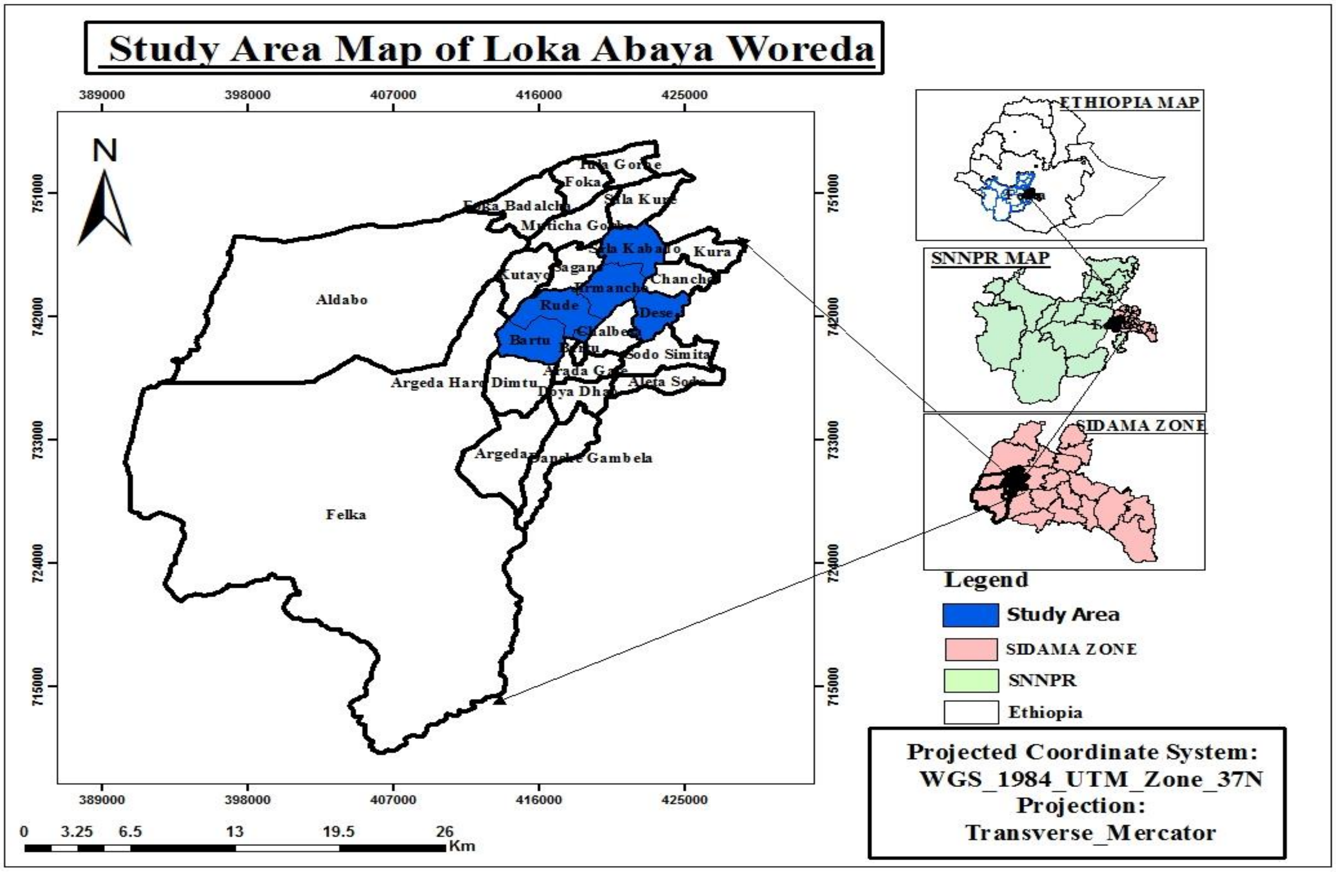


3. RESEARCH METHODOLOGY

3.1. Description of the study area

The study was conducted in five Kebeles of Loka Abaya district in Sidama Zone of the Southern Nation Nationalities of Ethiopia. Loka Abaya is bordered in south by the Oromiya Region, in southwest by Lake Abaya, in west by Wolayita Zone, in north by Boricha district, in northeast by Dale district, in east by Shebedino district and in southeast by Chuko district. The total area of Loka Abaya district is about 1,190 km^2 and its altitude ranges from 1500-1768 meter above sea level (Bewket *et al.,* 2015). The major part of the districts is characterized by semi-arid which constitutes fifteen Kebeles along with a few sub-humid areas which includes about ten Kebeles. Based on the Census conducted by the CSA (2007) this district has a total population of 124,771 of whom 63,050 are men and 61,661 women; 1.07% of its population are urban dwellers.

The district is known for its maize (*Zea mays*), haricot bean (*Phaseouls vuligaris* L.), tef (*Eragrotis teff*), coffee (*Coeffa arabica*), enset (*Ensete ventircosum*), sweet potato (*Ipomoea batatas* L.), cow pea (*Vigna unguiculata* L.) etc. production (Girma and Merga, 2017). The farmers of Loka Abaya have good experiences in intercropping, double and multiple cropping of cereals and legumes, to efficiently utilize the available land resources. During the first cycle, maize is often intercropped with haricot bean. As the first cycle, haricot bean (legume) matures a second cycle haricot bean relay copped or during the second cycle tef may be cropped after removing the maize biomass. This is due to the fact that low land legumes and tef are short season crops compared to maize (Girma and Merga, 2017).



Scale: 1:10,000

Figure 4: Administrative Map of Loka Abaya (CSA, 2017)

3.1.1. Topography

The topography of the district is diverse not level or smooth, rather rugged having many outcrops than plants or trees and its surface cross-cut by various gorges and river valleys that flow west wards. Because of its physiographic setting, it has steep slopes, rivers like Bilate, valley and protected area like Loka Abaya National Park with its diverse fauna and flora. Deep Fluvial deposits are dominating that lands and river banks. The substitutes of fluvial (fluvi soils) are pumas, while soils at uplands and on steep slope are dominated by shallow luvisols and deep wit sols

3.1.2. Climate

The agro-ecology of Loka Abaya district is considered as mid and lowland. It is characterized by a warmer climate following the traditional classification of agro-ecological zones in Ethiopia. According to Bewket *et al. (*2015), the region is characterized by hot and warm condition and experienced recurrent drought in recent years.

The rainfall pattern of the area is bi-modal type in which the short rainy season is from March to April, while the main rainy season is from June to September. However, the rainfall season extends from March to September. The annual minimum and maximum temperature of the area is 17 and 20 ^{O}C, respectively and the annual rain fall is about 900-1400 mm (Bewket *et al.*, 2015). High temperature during dry seasons and erratic rainfall and moisture stress is the common climatic problem in the study area.

3.2. Research Design and Sampling Methods

The study used a cross-sectional survey research design as its framework to guide the process of data collection. Cross-sectional survey research design was the collection of data mainly using questionnaires or structured interviews to capture quantitative or qualitative data at a single point in time. In this cross-sectional survey research design, farm households of host and non-host or adopters and non adopters of conservation agriculture were interviewed, focus group discussion (FGD) and key informant interview (KII) were conducted.

3.2.1. Sampling Techniques and Sample Size

Multi-stage sampling technique was employed. First purposively, Loka Abaya district was selected from the 19 rural districts of Sidama Zone of SNNPR state, due to the fact that it was one of the districts where CA was promoted with maize production. Purposive sampling technique was adopted to select five CA beneficiary Kebeles (Rude, Bartu, Dessie, Sala Kebado and Jirmancho) in which SIMLESA/HARC and DCG/HU CA projects have been implemented and promoted over the last 5 years. The inclusions of many Kebeles are to get enough number of CA beneficiaries to pursue the study in order to understand the contribution of CA in terms of food security improvement and adaptation to the impacts of climate change. In the second stage, the stratified sampling techniques were used to identify CA adopters from non-adopters. The adopters in each Kebeles are selected using purposive sampling method since the number of adopters is small compared to non-adopters to draw total 72 respondents. The non-CA adopters are selected using simple random sampling method since the majority of farmers in each Kebeles are non adopters of CA technologies and 72 of them were drawn. The sample size was determined by using simplified formula, suggested by Yamane (1967), at 95% confidence level, with 6% level of precision

$n= N/1+N (e^2)$…………………………………………………1

n = sample size, N= population proportion, e=error term =6.02%

$n= 304/1+304(0.06)^2 = 144$

$n = 144$

Table 1: Distribution of adopter and non-adopter of conservation agriculture sample households in five Kebeles of Loka Abaya district

No.	Name of Kebeles	Total population			Total HHs	Beneficiary Households		Total	Sampled Adopters		Total
		M	F	T		Adopters of CA	Non CA adopters		Adopters	Non- adopters	
1	Rude	1,833	1,777	3,611	722	16	16	32	4	4	8
2	Bartu	1,653	1,573	3,225	645	16	16	32	4	4	8
3	Jirmancho	2,029	1,896	3,925	785	40	40	80	22	22	44
4	Dessie	1,563	1,458	3,021	604	40	40	80	20	20	40
5	Sala Kebado	2,476	2,567	5,043	1,009	40	40	80	22	22	44
Total					3765	152	152	304	72	72	144

Source: CSA and Sidama ZFED, 2017

3.2.2. Data types and sources

Both quantitative and qualitative data were used for this study. Qualitative data focused on the expressions and feelings of smallholder farmers, key informants, and focus group discussion participants. Quantitative data types were obtained from sample household interviews that can be measured and quantified.

The data was collected from both primary and secondary data sources. The primary data sources were male and female respondents, from focus group discussions and key informants. Whereas, secondary data was obtained from agricultural office, internet sources, document files, records and reports of GOs and NGOs, research articles, and metrological data (Rainfall and Temperature data of past 30 years) were obtained from Ethiopian Metrological Agency.

3. 3. Data collection methods

The method of data collection included Household Survey, Focus Group Discussions (FGDs), Key Informant Interview (KII). For household survey semi-structured questionnaires were developed, while checklists for FGDs and KII were developed and used. Semi-structured questionnaires were pre-tested before main interview and qualified best for the intended purpose. A total of ten FGDs were conducted; two focus group discussion in each Kebeles having five household head members in each group. Only five household head were selected mainly because of the shortage of time and lack of interest from the participants to spend more times on discussion. The FGDs were selected purposively. 32 key informants, who included 10 DAs, 20 elders and 2 officials from district, were included. The discussion was aimed to assess their understanding about climate change, the CA contribution to food security and its role to climate change adaptation for smallholder farmers.

3.3.1. Household Survey

Three professional enumerators, assistant enumerators and one researcher assistant was recruited and trained on the contents of the questionnaire and interviewing techniques. The questionnaire was pre-tested to make changes on the questionnaire before the enumerators start the actual interviewing at each sample household level. Then, the primary quantitative data was collected under close supervision of the researcher and his assistant. Secondary quantitative data on population and households of study Kebeles, CA beneficiaries and non- beneficiary's lists and administrative map of Loka Abaya district was obtained from SNNPR, Sidama Zone, and Woreda Finance and Economic Development Offices, WAO.

3.4. Method of Data analysis, Interpretation and Econometric Model Specification

Data from the field was edited, coded and cleaned to ensure consistency, uniformity and accuracy. Qualitative and quantitative data sets were entered in to computer software analysis. Then it was analyzed using appropriate statistical analysis procedures. Statistical package for social science (SPSS 2002) version 16.0 was used for analysis. Chi-square test was used to see the degree of association between two categorical variables whereas; independent T-test was used to compare means of two continuous variables. Microsoft excel was used to run Rain fall and temperature data.

Objective One i.e. assessing the existences of climate changes at the study area. In order to assess the existences of climate change at Loka abaya district, climate data (Temperature and rain fall data for thirty year from Ethiopia meteorological agency was obtained and for this trend analysis was done by using excel sheet. Secondly data was obtained from selected key informants, households, DAs and different officials of the district to assess the perceptions of households for the existences of climate change and for this descriptive statistics such as mean, Chi- square test and percentage were used.

Objective Two i.e. assessing the contributions of CA on food security at Loka Abaya district was analyzed by using **Cobb-Douglas Production Function**.

This research used maize production as a measure of the importance of CA on household food security. The basic reason was, maize is considered as basic food crop and that without it household is food insecure.

The Cobb-Douglas form of production function has some well known properties that justify its wide application in economic literature (Henderson and Quandt, 1971). It is a homogeneous function that provides a scale factor enabling one to measure the returns to scale and to interpret the elasticity coefficients with relative ease. It is also easy to estimate and mathematically manipulate.

The Cobb-Douglas production function makes several restrictive assumptions. It is assumed that the elasticity coefficients are constant, implying constant shares for the inputs. The elasticity of Substitution among factors is unity in the Cobb-Douglas form. Moreover, this being linear in logarithm, the output is zero if any of the inputs is zero, and the output expansion path is assumed to pass through the origin. It is also argued that if interest rests on efficiency measurements and not on an analysis of the general structure of the underlying production technology, the Cobb-Douglas specification provides an adequate representation of the production technology. In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks. It is less affected by multicollinearity problem and less suffered from degrees of freedom (Rahman *et al.*, 2012)

The estimation considered the rain -fed maize production for both adopters' and none adopters. The function is specified as follows;

$$\mathbf{A}=\boldsymbol{\beta}0\boldsymbol{Fert}^{\boldsymbol{\beta}1}\boldsymbol{Seed}^{\boldsymbol{\beta}2}\boldsymbol{Land}^{\boldsymbol{\beta}3}\boldsymbol{Lab}^{\boldsymbol{\beta}4}\boldsymbol{Ox}^{\boldsymbol{\beta}5}\boldsymbol{\mu i}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{2}$$

However, the generalized modified linear logarithmic production was used. It is expressed as follows:

$$\ln Ai = \beta 0 + \beta 1 \ln Landi + \beta 2 \ln Labi + \ln \beta 3 Ferti + \beta 4 \ln Seedi + \beta Oxi\mu i\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where: (Ai) is expected rain-fed production in (quintals?)

Lani is the land allocated for maize production for each group of farmers in hectors

Ferti is the amount of fertilizer used in the production function (kg)

Labi is household labor units supplied for maize production;

Seedi is the amount of maize seed used in maize production (kg)

Oxi is number of oxen used in maize production

βs are the parameters to be estimated and μi are the stochastic error terms.

μi are the stochastic error terms

For each group of farmers a separate production function was estimated as follows:

$\ln A1i = Xi\beta 1i + \mu 1i$, when A=1 (adopters) ……………………………………………..…4

$\ln A0i = Xi\ \beta 0i + \mu 0i$, when A =0 (non- adopters)………………………………………5

Where: Xis are the vectors of variables that are employed in maize production such as seed labor, land, oxen/draft power and fertilizer

$\mu 1i$ & $\mu 0i$ are the error terms.

Multiple Linear Regression Analysis

Multiple linear regression analysis was used to estimate maize production for both adopters and non adopter households. The t- test was used to test if estimated maize production for two groups were statistically different. Comparing the yields by using T-test between adopters and non-adopters just provides indicative differences in yields but does not measure the impact of CA. There are other methods such as propensity score matching techniques that are appropriate for measuring the contribution of CA to the yield difference. My sample is not large enough to deploy the propensity score matching techniques to measure the impact of CA. My idea was just to compare the production efficiencies between adopters and non-adopters.

Relationship between the independent variables and the dependent variable was established by using of the following regression formula:

$Y= \beta 0 + \beta 1 X 1 + \beta 2 X 2 + \beta 3 X 3 + \beta 4 X 4 + \beta 5 X 5 + \varepsilon$………………………..6

Where: Y = Maize yield (Dependent Variable);

X 1 – X5 = Independent Variables;

X 1 = Land size;

X 2 = Amounts of labor

X 3 = Improved Seed

X4 = Fertilizer used by adopter and non adopter households

X 5 = Availability of Oxen/draft power access

β_0 = Coefficient of the model

$\beta_1 - \beta_5$ = Beta Coefficient of Determination

ϵ = Stochastic Error Term

Objective Three: assessing the Contribution of conservation agriculture on climate change impacts adaptation at Loka Abaya district: descriptive and inferential statistics, such as mean, median, standard deviation, percentage, frequencies, tables, etc was used.

Objective Four: Determinants of Conservation Agriculture adoption at Loka Abaya Districts, is analyzed by using the **Binary Logistic Regression Model**

$$Pi = \frac{1}{1+ \quad e^{z(i)}} \quad = \frac{e^{z(i)}}{1+ \quad e^{z(i)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..7$$

Where,

$$Zi = \beta_{o} {}_{+}\textstyle\sum_{i=o}^{n}.\beta ixi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.8$$

Where, Pi is the probability of adoption of CA technology for the i^{th}farmer and Pi ranges between 0 and 1.

- Zi is the function of a vector of n explanatory variable
- e^{-} Is the base of natural logarithms
- i- is observation on variables for the adoption model
- Bo is the constant term
- Bi are unknown variables
- n is number of identified variables for the study

Hence, the above equation can be expressed as

$$pi = \frac{1}{1+ \quad e^{-(\beta_{o}+\beta iXi+\cdots\beta nXn)}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..9$$

Pi is nonlinearly related to Zi (i.e., Xi)

If Pi, the probability of adoption of CA, is given by (1), then (1 − Pi), the probability of not

Adopting CA, is

$$1 - pi = \frac{1}{1 \quad + e^{z(i)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

$$\frac{pi}{1-p} = \frac{1+ \quad e^{z(i)}}{1 \quad e^{z(i)}} = e^{Z(i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

Now Pi/ (1 −Pi) is simply the odds ratio in favor of adopting CA as explanatory variables changes the ratio of the probability that a farmer will adopt CA to the probability that he/she will not adopt CA.

Now if we take the natural log of (5), we obtain logistic model as follow:

$$\mathrm{L}\mathbf{i} = \mathbf{ln}\,\frac{\mathbf{Pi}}{\mathbf{1-p}} = \mathbf{Zi} = \boldsymbol{\beta}_{\mathbf{o+\beta 1X1+\cdots.\beta nXn}}$$

That is, Li, the log of the odds ratio, is not only linear in X, but also linear in the parameters. Li is also called the logit. When we put stochastic error term (disturbance term) ∪i in to account, we write the model (12) as follows:

$$\mathbf{Li} = \mathbf{Zi} = \boldsymbol{\beta}_{\mathbf{o+\beta 1X1+\cdots.\beta nXn+\cup i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{13}$$

First of all for estimating the model, it is important to check for the presence of multicollinearity among the variables. Multicollinearity occurs when two or more predictors in the model are correlated and provide redundant information about the response. It can have two effects on the regression analysis. First, the regression parameters will be unstable from sample to sample because the standard errors of the regression parameters are very large. Second, the interpretation of the regression parameters as the effect of one predictor while holding the other predictors constant is not very informative. This is because if predictors are highly correlated, holding one predictor constant immediately limits the extent to which the other predictors (Jennifer, 2004)

In this analysis, I used Coefficient of contingency (CC) for categorical independent variables such as sex of the households, marital status, labor availability, extension contact, soil fertility status, incentives and training and variance inflation factor (VIF) for continuous independent variables (such as age, level of education, farming experiences, land size and family size) to check the presence of multicollinearity problem.

The contingency coefficient was computed as follow:

$$\mathbf{CC}=\sqrt{\frac{x^2}{n+X^2}}\text{...}\mathbf{14}$$

Where, CC is coefficient of contingency, χ^2 is chi-square value and n = total sample size

And VIF was computed as follow:

$$\mathbf{VIFi} = \frac{1}{1-Ri^2}\text{...}\mathbf{15}$$

Where; VIF is variance inflation factor, $R^2{}_i$ is the coefficient of determination of the regression equation

3.5. Operational Definition of Variables

This study focused on the conservation agriculture in the study area. Thus, variables employed were the characteristics of household heads. First, the outcome variables (variables used as dependent variable) are defined and described. In this study adoption of conservation agriculture is a polychromous dependent variable which takes the value 1 if the household adopt CA and 2 if the households do not adopt CA technology.

The independent variables that expected to affect adoption of conservation agriculture technology of rural households in the study area are also defined and discussed as follows.

Age of the household head: this is a continuous variable and is measured in terms of number of years of the respondents. Since age is a factor that normally makes household head to have more experiences it is assumed that age would have a positive relationship with dependent variable.

Sex of household head: sex of a household head is a dummy variable (i.e. =1 if household head is male and =2 if household head is female).

Education level of household head(ED):- education refers to the level of formal and informal education and was measured in terms of ability to read and write and enrolment in primary, secondary schools or above. Educational level as a variable helping exposure to information, but also positively affects a households ability to decide for adoption of CA technology.

Extension contact (EXT): is the number of times the household head contact with the extension personnel such as Das during the production year. It is a dummy variable. This is because the message/contents that the farmers gain from extension agents help them to initiate to use risk aversion strategies that seek diversification of income sources. Positive relationship is expected between extension contact and livelihood diversification.

Table 2: Variables description

Independent Variables	Nature	Measurements
Sex	Dummy	1 for male and 2 for female
Marital status	Categorical	1 for single, 2 for married, 3 for divorced and 4 for widowed
Labor availability	Dummy	1 for Yes and 2 for No
Extension Contact	Dummy	1 for Yes and 2 for No
Availability of CA training	Dummy	1 for Yes and 2 for No
Availability of CA incentives	Dummy	1 for Yes and 2 for No
Soil fertility status	Categorical	1 for more fertile, 2 for moderate fertile and 3 for less fertile
Level of education	Categorical	Number of Grades
Age	Continuous	Number Years
Farming experiences	Continuous	Number Years
Land size	Continuous	Hectares
Family size	Continuous	Number of person

3.6. Descriptive statistics

This section discussed the specified variables included in the model using descriptive statistics and econometric analysis. The descriptive statistics clearly described the results of demographic, socio-economic, farm characteristics and institutional factors by average, percentage, standard deviation, minimum and maximum while econometric model such as cob-Douglas Production function with multiple linear regression analysis was employed to estimate rain -fed maize production for both adopters and none adopters and, Binary logistic regression model which was used to assess the factors affecting adoption of Conservation Agriculture at the study area.

4. RESULT AND DISCUTION

4.1. Demographic characteristics of the household

4.1.1. Sex of Household head

The majority (78.5 %) of the total sample householders were male headed, while the remaining 21.5% was female headed. Similarly, the majority of CA adopters (81.9%) and non-adopters (75.0%) were also male headed household, while the reimaging 18.1% and 25.0% of adopters and non adopters of CA were female headed households respectively. The survey result in Table 2 indicated that the relation of sex of household head and household's decision on adoption of CA is not significant at 5 % significant level.

4.1. 2. Marital status of the Households

The majority of both CA adopter (69.4%) and non-adopter (58.3 %) households were married. The remained proportions' were single, divorced or widowed (Table 2). Significant proportions of sample households have similar marital status in study area. Greater than 63.9 % of them are married. Marital status of the sample households had no significant ($p<0.05$) association with adoption of CA. This shows that marital status is not determining factor for CA adoption in the study area since most of the farmers have similar marital status (Table 2)**.**

4.1.3 Religion

As it is indicated in Table 2 below, 124 (86.1%) of the households are followers of Christianity religion, while the remaining 9.7% were Muslims. From the total sample respondents 90.3% of CA adopters and 81.9% of the non adaptors were Christians

4.1.4. Educational Status of the Household

The survey results of the sample households indicated that majority of CA adopter households are well educated compared to non CA adopters. Only 2.8% of the households who were the adopters of CA were not able to read and write and the rest 6.9% could read and write, 41.7% attended primary school, 37.5% secondary and preparatory school and 11.1% had collage diploma and above. But according to the same survey results, 34.7% of the non CA adopters were not able to read and write; this suggest that education could be considered as factor that affected the rate of CA adoption. .

The results indicated that, levels of education had significant ($p<0.05$) association with adoption of CA (Tbale 2). This result is similar with the finding of Fikiru (2009), who stated that education have positive relation with adoption of conservation tillage as most of the households were different in status of education. On the other hand erosion problems as well as knowledge related to soil and water conservation and hence they adopted the technology better than less educated households.

Table 3: Demographic characteristics of the household

		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value	Mean	Min	Max	SD	T-value
Variable		N	%	N	%	N	%							
Sex	Male	59	81.9	54	75.0	113	78.5	1.028	0.311NS				-	-
	Female	13	18.1	18	25.0	31	21.5	-	-	-	-	-	-	-
Age	Practice CA	72	-	-	-	-	-	-	0.68NS	38.6	23	52	7.23	-0.41
	Do not practice CA	72	-	-	-	-	-	-	-	39.3	22	62	11.7	39.3
Household head	Male headed	59	81.9	54	75	113	78.5	1.028	0.311NS					
	Female headed	13	18.1	25	25	31	21.5							
Marital status	Single	13	18.1	15	20.8	28	19.4	2.356	0.311NS					
	Married	50	69.4	42	58.3	92	63.9							
	Widowed	9	12.5	15	20.8	24	16.7							
Religion	Christian	65	90.3	59	81.9	124	86.1	2.100	.350NS					
	Muslim	5	6.9	9	12.5	14	9.7							
	Pagan	2	2.8	4	5.6	6	4.2							
Education	Illiterate	2	2.8	25	34.7	27	18.8	47.469	0.000Sig					
	Read and write	5	6.9	17	23.6	22	15.3							
	Primary school grade(1-8)	30	41.7	24	33.3	54	37.5							
	Secondary and Preparatory	27	37.5	4	5.6	31	21.5							
	College diploma and above	8	11.1	2	2.8	10	6.9							

NS =non significant at 5% probability leve

4.1.5. Age of the households

The average age of the respondent was 38.67 years with standard deviation of 9.84; the minimum age was 22 while the maximum age was 67 years. The average age of adopters and non-adopter households of CA were 38.62 and 39.29 years with standard deviation of 7.28 and 11.679, respectively. The minimum and maximum age of CA adopters was 23 and 52 respectively. The minimum and maximum age of non adopters was 22 and 62 respectively. The statistical analysis of mean age difference of adopters and non-adopters was non-significant ($p<0.05$) (Table 2). The results indicated that when age of household increased, the level of adoption for new technology will be decreased and these results are similar with Workneh (2007), which showed that as the age of respondents increase, the adoption of improved bee box technologies decrease.

4.1.6. Family Size of the households

The average family size of the respondent household was 4.5 persons with standard deviation of 2.7. The survey results showed that the average family size of CA adopters and non adopters households were 4.7 and 4.3 respectively. The average family size of the adopter households is not that much greater than the average family size of non-adopters and therefore it is non-significant at 5% probability level (Table 3). The minimum family members of a household were one person while the maximum members of a household were 8 persons.

4.1.7. Farming experience

The average farming experience of a household was 20.5 years with standard deviation of 23.0; the minimum was 1 year while the maximum was 41 years. Moreover, the mean farming experience of CA adopter and non-adopter households were 21.8±30.6 and 19.3±11.3 years respectively. The results revealed that CA adopter households were relatively more experienced in farming than non-adopter households although the difference between the two groups was not statistically significant ($p<0.05$) different (Table 3).

4.1.8. Farm size of the households:

The average farm size of adopters was 1.1 ha with standard deviation of 0.58, whereas the average land size of non-adopters was 1.2 ha with standard deviation of 0.59. The overall average land size was 1.14 ha, the minimum was 0.05 ha and the maximum was 2.50 ha. All the households own the land by receiving from Kebeles or taking as gift from their forefathers. The mean difference of land size of adopter and non-adopters sample households was not significantly ($p<0.05$) different (Table 3).

4.1.9. Farm distance from home

The average distance of the households' residence from their farm plots was 0.163 Kms, and it ranged between 0 and 10 Kms. The average plot distance of single trip from home for adopter households was 0.19 Kms with standard deviation of 0.274 Kms whereas, the average distance for non-adopter households was 0.14 Kms with standard deviation of 0.159 Kms. The mean difference of plot distance of sample adopter and non-adopter households was non-significantly ($p<0.05$) different (Table 3). This was probably due to most farmers possess the land and live there at the same time without traveling to longer distance from their home and hence, the variation between the groups was not big.

Table 4: Age, family size, farming experience and farm distance of sampled households in relation to CA adoption in Loka Abaya district

Variables	Group of respondents	N	Mean	Min	Max	SD	t-value	P-value
Age	Practice CA	72	38.6	23	52	7.23	-0.41	0.68NS
	Do not practice CA	72	39.3	22	62	11.7		
Family size	Practice CA	72	4.7	1	8	1.6	1.41	0.54NS
	Do not practice CA	72	4.3	1	8	1.9		
Farming Experience	Practice CA	72	21.8	4	33	30.6	0.64	0.56NS
	Do not practice CA	72	19.3	1	41	11.3		
Farm size	Practice CA	72	1.1	0.05	2.25	0.58	-1.53	0.13NS
	Do not practice CA	72	1.2	0.25	2.50	0.60		
Farm distance	Practice CA	72	0.20	0.01	2	0.27	1.30	0.20NS
	Do not practice CA	72	0.14	0.0	1	0.16		

NS and Sig are significance and non significance at 5% probability level of confidence

4.2. Socio-economic characteristics of households

4.2.1. Livestock ownership:

Almost all (99.3%) of the respondent households owned livestock (Table4). The average livestock holding size of the respondent households was 3.1 TLU with standard deviation of 2.98 TLU. The average TLU of adopter households was 1.65 with standard deviation of 1.47 whereas; the average TLU of non-adopter households was 1.58 with standard deviation of 1.51 (Table 4). The households in the study area were engaged in animal husbandry for different purposes. These include traction power, income generation, social dignity, family consumption, as well as use the animals' dung to fertilize the farming land (WOA, 2017). Having large number of livestock is considered as basic indicator of wealth situation of farming community at the study area. But, there was insignificant mean difference of livestock ownership of CA adopters and non-adopters households at 5% level (Table 4). This result tells us that owning or not owning livestock had no contribution for the adoption of conservation agriculture.

4. 2.2. Soil fertility status:

The survey results showed that 79.2% of CA adopters' farm soil fertility condition was more fertile, while 5.6% soils were less fertile. Compared to this, 9.9% of the land owned by non-adopter farm soil was more fertile while 66.7% was less fertile. The farmers who have relatively more fertile land adopted CA technology easily than those who have less fertile land and also the practicing of conservation agriculture increased the soil fertility status of their farm. The statistical analysis showed that there was a significant ($p<0.05$) difference in soil fertility status between adopter and non-adopter households. This is probably due to farmers who have more fertile land are more interested on sustainable farming practices like CA than those farmers who have less fertile land.

4.2.3. Access to incentives to adopt CA

Conservation agriculture adopters (90.3%) and non-adopters (29.2%) sample households received one or more type of agricultural inputs as incentive from different CA running projects such as SIMLESA and DCG to practice CA whereas, 7.9% and 70.8% of adopters and non-adopters, respectively, did not receive any agricultural inputs as incentive (Table 4). The study Kebeles as well as the district is mostly affected by climate change impacts such as drought, flooding and irregularity of rain fall during major rainy seasons. For this reason, different CA running projects in the study area provided incentives in one way or another in order to encourage the farmers to adopt the CA technologies. The most widely and commonly provided agricultural inputs in the form of CA incentives were improved seeds of maize and haricot bean, fertilizer, farm tools, herbicides and sprayer. But type and amounts and of all inputs were not provided in similar system for all adopters since the projects run CA by using their own systems. The percentage of farmers who received incentive and adopt CA was by far greater than the percentage of farmers who did not receive incentive. The statistical analysis showed that there was significant and positive relationship between access to incentives and level of CA technology adoption. This implied that access to incentive significantly and positively affected adoption of CA in the study area.

Table 5: Socio-economic characteristics of households by categorical variables with CA adoption

		Practice CA (N=72		Do not practice CA (N=72		Total sample (N=144)		X^2	P value	Mean		SD		t-test
Variable		N	%	N	%	N	%			CA	CP	CA	CP	CA
Do you have livestock?	Yes	65	90.3	57	79.2	122	84.7	3.40	0.064	1.65	1.58	1.47	1.51	-2.378
	No	7	9.7	15	21.8	22	15.3	0.45	0.000*					
Soil fertility status of your farm?	More fertile	57	79.2	7	9.9	64	44.4	78.20	0.000*	-	-	-	-	-
	Moderate fertile	11	15.3	17	23.9	28	19.4							
	Less fertile	4	5.6	48	66.7	52	36.1							
Labor availability?	Yes	14	19.4	23	31.9	37	14	2.95	0.086	5.39	4.519	1.740	2.325	2.556
	No	58	80.6	58	68.1	107	58							
Get CA Incentives?	Yes	65	90.3	21	29.2	86	59.7	55.891	0.000*	-	-	-	-	-
	No	7	9.7	51	70. 8	58	7							
Types of incentives you	Fertilizer	3	5.4	1	.6	4	2.8	40.0	0.000*	-	-	-	-	-

get?	Seeds	1	1.8	3	10.7	4	2.8	-	-	-	-	-
	Herbicides	1	1.8	3	10.7	4	2.8	-	-	-	-	-
	Fertilizer & seeds	42	75	20	27.8	62	43.1	-	-	-	-	-
	Herbicides &seeds	5	8.9	1	3.6	6	4.2	-	-	-	-	-
	All	4	7.1	0	0.0	4	2.8	-	-	-	-	-

4.2.4. Feed type and availability

The survey results revealed that the majority of adopter households obtained feed for their livestock from non-farm outputs (Table 5). Accordingly, 55.9% of the respondents feed their livestock on Furishika and graze individual lands, while and 29.4% of them feed Furishika, graze on individual and communal lands. Whereas, 58.7% of non adopter respondents feed their livestock crop residues from cereals and legumes and letting them to farm after harvest. These results indicated that, adopter households used non farm output (Furishika and different grazing lands) rather than using crop residues to feed their livestock since they used crop residue to cover their farm or soil and also they used the crop residues as a fertilizer and this was significant at 5% level.

Table 6 : livestock feed availability

		Practice CA(N=72)		Do not practice CA(N=72)		Total sample (N=144		X^2	P value
Variable		N	%	N	%	N	%	88.6	0.000*
What do you feed for your livestock?	Crop residue from cereal	0	0.0	2	3.2	2	1.5		
	crop residues from legume	1	1.5	1	1.6	2	1.5		
	Furishika	1	1.5	0	0.0	1	0.8		
	Furishika and individual grazing land	38	55.9	6	9.5	44	33.6		
	Furishika, individual grazing and communal grazing land	20	29.4	5	7.9	25	19.1		
	Legumes crop residues, individual and communal grazing land	8	11.8	1	1.6	9	6.9		
	Crop residues from cereals and legumes and letting them to farm after harvest	0	0.0	37	58.7	37	28.2		
	Furishika, individual grazing land and letting them to farm after harvest	0	0.0	2	3.2	2	1.5		
	Crop residues from cereals, individual grazing land and letting them in to farm after harvest	0	0.0	9	14.3	9	6.9		

4.3. Institutional Characteristics of the household in relation to CA Technology adoption

Characteristics of households that are more related and connected to their perception towards CA technologies are presented. They are described as household's perception on CA technologies in increasing crop yield, relative advantage over conventional agriculture, compatibility with existing system, and experimentation in small plots of land. The households' preference on buying non-selective herbicides and level of needed information are also illustrated.

4.3.1. Level of CA information need by households:

Majority of the sample households needed information about the CA technology. From this 93.1 and 97.2 of adopters and non adopters of need information about CA whereas 6.9 percent and 2.8 of adopters and non adopters do not need information about Ca technology. As indicated in table above, 20.1 percent of adopter and 90.3 percent of non-adopter households needed the whole package of CA whereas 53.6 percent of adopters and 2.8 percent of non-adopters needed some information of CA. The amount of package of information adopters needed was lower than non adopters since adapters were already practicing CA so that they had more information of CA than non adopters. Even if all households were supposed to be familiar of CA concepts directly and indirectly and principles through one or the other tools of the projects, still majority of both adopters and non-adopters households were seeking more information on CA. The statistical analysis at 5 % significant level of Chi-square test showed that there was significant association on level of CA information needed and adoption of CA.

4.3.2. Compatibility of conservation agriculture technology with the existing farming system

Survey results indicated that, 93.1% of the adopter and 61.1% of non-adopter sample households agreed that CA technologies are compatible with the existing system. But the remaining 6.9% of adopter and 39.9%of non-adopter sample households stated that CA technologies are not compatible to existing system. The respondents further described that how CA is compatible with the existing agriculture systems and solve existing problems. According to the survey results81.4% of adopters and 45.8% of non adopters believe that CA technologies are compatible with dry/hot condition and 12.9% of adopters and 15.3%of non adopters believed CA technologies are compatible with limited oxen (Table 6). Those farmers who believed that CA is not compatible with existing farming system thought that minimum tillage does not agree with what we do so far starting from our forefathers and learnt from extension agents. The existing system comprises socio-cultural beliefs and values, community needs and current farming system. The statistical analysis showed that there was significant ($p<0.05$) association on the households understanding in compatibility of CA technologies with existing system and adoption of CA.

4.3.3. Households' awareness about conservation agriculture technology:

According to the survey results all adopters and 95.8% of non-adopters households reported that they have heard about CA technology in one or the other ways, whereas, 4.2%of non-adopter households did not hear about CA technologies. The statistical analysis showed non-significant association on the households' awareness about CA and adoption CA technologies.

4.3.4 .Time length after household aware about conservation agriculture:

Depending results in Table6 below, 91.7 of adopter and 15.5 percent of adopter households heard about CA technology for two and more than two years. Whereas 8.3% and 55.6% of non-adopter households heard about CA technologies for two years respectively. Farmers who had long time exposure on CA technologies adopted more than those farmers who had recent time exposure on CA technologies since this will give time for farmers to think and decide whether to adopt new technologies or not. The statistical analysis at 5 % significant level of Chi-square test showed a highly significant positive relationship between the exposure time on CA technologies and adoption.

4.3.5. Perception of household on conservation agriculture over conventional agriculture:

Most (97.2 %) of adopter and 70.8 % of non-adopter households said CA is better than conventional agriculture, but the remaining 2.8 % of adopters and 29.2 %of adopters said that CA is not advantageous compared to conventional agriculture. Farmers can easily compare and adopt the new technology with the others or existing one if they understand the basic concept and benefit of the new technology very well. The statistical analysis at 5 % probability level of Chi-square test showed that there was a significant relationship on perception of households on CA over conventional agriculture and adoption of CA.

4.3.6. Possibility of experimentation of conservation agriculture in small Farm plot:

According to the survey results in Table6, 94.4% of adopter and 72.2% of non-adopter households agreed that CA can easily be experimented in small plot of land, whereas, 5.6% of adopters and 27.8% of non-adopter households didn’t agree on easy experimentation of CA on small plot of land. The statistical analysis at 5 % significant level of Chi-square test showed that there was a positive significant association on the households understanding on easily extermination of CA technologies in small plot of land and adoption of CA.

Table 7: Institutional characteristics of the household in relation to CA technology adoption

Variable		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
		N	%	N	%	N	%		
Do you need more info about CA?	Yes	67	93.1	70	97.2	137	95.1	0.31	0.315
	No	5	6.9	2	2.8	7	4.9		
How much info you need?	All	15	20.1	65	90.3	80	55.6	69.20	0.000*
	Some	53	74.6	6	8.3	59	41.5		
	Little	4	5.3	1	1.4	5	3.3		
Is CA compatible with your farming system?	Yes	67	93.1	44	61.1	111	77.1	27.0	0.000*
	No	5	6.9	28	39.9	33	22.9		
In what farming system is CA compatible?	Hoe culture	0	0.0	1	1.4	1	.7	7.60	0.107
	Limited oxen	4	5.6	18	25.0	22	15.3		
	soil type suitability	2	2.8	11	15.3	13	9.0		
Easy of experimentation of CA on small farm?	Yes	68	94.4	52	72.2	120	83.3	12.90	0.002*
	No	4	5.6	20	27.8	24	16.7		
What is your perception on CA over CP?	Good	70	97.2	51	70.8	121	84.0	18.70	0.000*
	Bad	2	2.8	21	29.2	23	16.0		
Have you ever heard about CA?	Yes	72	100	69	95.8	141	97.9	3.10	0.080

	No	0	0.0	3	4.2	3	2.1		
Length of time you heard about CA?	<2 years	0	0.0	4	5.6	6	4.2	91.20	0.000*
	=2years	0	0.0	17	23.9	24	16.7		
	>2 years	6	8.3	40	55.6	68	47.2		
	≥2 years	66	91.7	11	15.3	46	31.9		

* =Significant at 5% level.

4.3.7. Household's CA practices and Perceptions

This section was concerned with comparing selected farming practices of CA with conversional agriculture. These were the three basic principles of CA such as minimum tillage, permanent crop cover/green manure, and crop rotation are described. According to the survey results in table 8, all of the adopter households and 25% of non adopter households retained crop residues on their farms. Whereas none of adopters and 75% of non adopter households did not retained crop residues. This result tells us that adopter households used crop residues to cover their farm than using to feed their livestock and this living crop residues and adoption of CA technology has significant and positive relationship at 5% probability level. Regarding to the importance of retaining crop residues on their farms, 63.5% and 15.3% of the adopter households replied that, continues use of crop residues resulted in increased moisture saving for their soil and decreased soil erosion respectively. But majority of non adopter households replied that they used their crop residues for another purposes and accordingly 86 % of the used crop residues as a fodder for their animals as feed and as fire wood.

Regarding to the Crop rotation, 66.7% of adopters and 11.1% of non adopter households were involved in crop rotation practices. Whereas 33.3%and 88.9 % of non adopter households didn't involved in crop rotation practices. Majority of non adopter households did not practiced crop rotation in the study area. According to the results revealed in table 8, the reason for not practicing crop rotation were lack of understanding about its importance (61.1%), shortage of land (13.9%), fear of bearing risk (11.1%) and unavailability of required seeds(1.4%). These results tells us that practicing crop rotation in the study area were affected by shortage of land lack of awareness about its importance, fear of bearing risk about new variety and un availability of required seeds and this in turn affected the adoption of CA for non adopter households and this was significant at 5% probability level. Concerning the tillage practices, 16.7% of adopter and 82.0 % of non adopter households practice intensive tillage in the study area. Whereas 82.3% of adopter households and 18.0% of non adopter households did not practiced intensive tillage or did not ploughed their farm in the study area. From this result we can understand that, most of adopter households did not involved in intensive tillage practice since they were engaged in minimum tillage systems and therefore practicing minimum tillage and adoption of CA technology had positive and significant relationship at 5% probability level.

Table 8: Household's CA practices and perceptions

		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
Variables		N	%	N	%	N	%		
Live crop residues on your Farm?	Yes	72	100.0	18	25	90	62.5	86.4	0.000*
	No	0	0.0	54	75	54	37.5		
Why you are living Crop Residue	Increase soil fertility	2	2.8	2	2.8	4	4.5	4.10	0.392
	Soil moisture saving	46	63.9	8	11.1	54	61.4		
	Decrease erosion	11	15.3	4	5.6	15	17		
	To get better yield	7	9.7	1	1.4	8	9.1		
	All	6	8.3	1	1.4	7	8.0		
If no, why?	Use as fodder for animals	-	-	1	1.8	1	1.8	-	-
	Us as fire wood	-	-	7	12.3	7	12.3		
	Both	-	-	49	86.0	49	86.0		
Do you use crop rotation?	Yes	48	66.7	8	11.1	56	38.9	46.7	0.000
	No	24	33.3	64	88.9	88	61.1		

Reason Crop rotation?	Increase soil fertility & crop yield	5	6.9	2	2.8	7	4.9	2.4	0.494
	Break life cycle of weeds, diseases &pest	8	11.1	2	2.8	10	6.9		
	Effective nutrient utilization	5	6.9	0	0.0	6	4.2		
Reason No Crop Rotation?	All	33	45.8	5	6.9	38	26.4	9.30	0.025*
	Shortage of land	8	11.1	10	13.9	18	12.5		
	Lack of understanding	6	8.3	44	61.1	50	34.7		
	Unavailability of required seeds	0	0.0	1	1.4	1	0.7		
	Fear of bearing risk	4	5.6	8	11.1	12	8.3		
Do you plough bed/farm?	Yes	12	16.7	59	82.0	64	44.4	89.40	0.000*
	No	60	83.3	13	18.0	80	56.6		

*=Significant at 5% probability level

4.3.8. CA Technology adoption Status of Households

4.3.8.1. Challenges households experienced during CA practice

Based on survey results households in the study area encountered many challenges in practicing conservation agriculture technologies. From these, 81.6% of non adopters face misunderstanding of fellow farmers, 43.1% and 36.1%of adopters encountered in difficulty in hand weeding and not getting enough advisory roles from the extension workers. The statistical analysis at 5 % significant level of Chi-square test showed that there was a positive significant association between the challenges the households encountered and adoption of CA technologies at the study area (Table8).

4.3.8.2. Difficult parts households faced in CA Technologies

The majority of households faced many difficult parts in practicing CA technologies. Survey results in table 8 indicated that 79.2% of adopters and 33.3% of non adopters faced weed management problems as a difficult part during practicing CA technology in the study area whereas 15.3% of adopters and 18.1% of non adopters faced Crop rotation problems at the same area. The statistical analysis at 5 % significant level of Chi-square test showed that there was a significant association between the difficult parts of CA the households faced during practicing of CA technologies at the study areas (Table8). This means that, the higher the existences of difficulties in practicing weed management and crop rotation, the lower the probabilities of CA adoption.

4.3.8.3. Comparing the worthiness of Buying herbicides and Hand Weeding

According to the results indicated in table8, 51.4 percent of adopters and 22.1% of non adopters agreed that buying herbicide is more worthy than hand weeding whereas 48.6% of adopters and 78.9% of non adopters did agree that hand weeding is better than buying herbicides. Based on result in table above, the preference of buying non selective herbicide is much worthy than hand weeding. The statistical analysis at 5% significant level of Chi-square test showed that there was a positive significant association on preference of buying non-selective herbicides and adoption of CA (Table8).

Table 9: CA Technology adoption Status of Households

Variable		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
		N	%	N	%	N	%	1.144	0.000*
Challenges you encountered in CA	Shortage of herbicides	4	5.6	0	0.0	4	2.8		
	Shortage Herbicide sprayer	4	5.6	1	1.4	5	3.5		
	Fertilizer & seed	2	2.8	3	4.2	5	3.5		
	Misunderstanding of fellow farmers	0	0.0	62	81.6	62	43.1		
	Difficulty in hand weeding	31	43.1	3	4.2	34	23.6		
	No enough advisor role	26	36.1	2	2.8	28	19.4		
	Scarcity of crop residues	5	6.9	1	1.4	6	4.2		
Which parts are difficult in CA?	Minimum tillage	0	0.0	0	0.0	3	2.1	13.735	0.001*
	Crop rotation	11	15.3	13	18.1	27	18.8		
	Weed management	57	79.2	24	33.3	75	52.1		
	Permanent crop Cover/residue	4	5.6	12	16.7	39	27.0		
Is it worth buying herbicide than hand weeding?	Yes	37	51.4	16	22.2	53	36.8	14.148	0.000*
	No	35	48.6	56	78.9	91	63.2		

*=significant at 5% level

4. 3.8.4. Weed management methods in CA

Based on survey results, households in the study area used different weed controlling mechanisms (Table 9). Accordingly, 65.3, 20.8 and 13.9% of adopter households used hand picking, herbicides and both herbicides and hand picking mechanisms to control weeds. Whereas 93.1% % and 6.9% of non adopter households used mechanical cultivation and hand picking to control weeds. From these results we can understand that majority of adopter households used hand picking mechanisms than using mechanical cultivation and herbicides.

Table 10: weed management methods by the households

		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
Variable		N	%	N	%	N	%	1.23	0.000*
How do you control weeds?	Hand picking	47	65.3	5	6.9	52	36.1		
	Using herbicides	10	13.9	0	0.0	10	6.9		
	Both hand picking and using herbicides	15	20.8	0	0.0	15	10.4		
	By mechanical cultivation tools	0	0.0	67	93.1	67	46.5		

4.3.8.5. Comparing CA with traditional farming system

In this section the study compared conservation agriculture with traditional farming/conventional farming system for different variables. These variables included were amounts of weed population, soil conditions, level of inputs households used for each farming systems and amount of yields obtained from each farm. According to survey based results CA adopter and 59.9% of non adopter households believed that there was higher weed population in each of their farm (Table 10). On the other hand, 30% of CA adopter and 34.7% of non CA adopters believed that there was medium weed population on their farm. Finally, 70% of adopter and 5.6% of non adopter households believed that there was lower weed population in their farm. This indicated that, CA can reduce amount of weed population through suppression by covering with crop residues and using of herbicide.

Regarding comparison of soil condition of each farm, 94.4% of CA farm plots and 48.6% of non CA farming systems had higher soil conditions, 4.2% of adopter and 44.4% of non adopter households had medium soil conditions on their farms and 1.4% of adopters and 6.9% of non adopter households had lower soil conditions on their farm plots. Soil condition here is the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental health, and promote plant, animal, and human health (Tasmania, 2014).Factors that determine soil condition include the formation and stability of aggregated soil particles, moisture content, degree of aeration, rate of water infiltration, and drainage. From these results, we can understand that CA had improved soil conditions for the adopter households at the study area through improving soil quality and soil health.

Finally, concerning the yield, 81.9% of CA adopter and 13.9% of non adopter households believed that they had got higher yields from their each farm, while 12.5% of adopter and 25.0% of non adopter believed that, they obtained medium amounts of yield from their each farm and non of CA adopters and 5.6% of non adopter and 61.1% households obtained lower yield from their each farm (Table10). In general, the amount of yield obtained by CA technology adopter households was greater much than non adopters and this had positive and significant difference at 5% probability level. These results were similar with the findings of Derpsch et al. (2010) and Kassam et al. (2009) in Latin America, Africa, and Asia which stated that CA yields are approximately 20-120% higher than those in conventional agriculture. Kaumbutho and Kienzle (2007) also found that in the Laikipia district in Kenya yields in maize, wheat, potato, and bean were 50-200% higher in CA than in conventional systems. Boahen et al. (2007) reported that maize yields in Ghana were up to three times higher with CA than in traditional slash-and-burn systems. According to Shetto et al. (2007), yields increased by 93-360% in maize and sunflower CA systems in Tanzania following adoption of conservation tillage (ripping) and a mucuna cover crop.

Table 11: Comparing CA with traditional farming system

		Practice CA(N=72)		Do not practice CA(N=72)		Total sample (N=144)		X^2	P value
Variables		N	%	N	%	N	%		
Weed population	Higher	0	0.0	43	59.7	43	30.3	81.5	0.000*
	Medium	21	30.0	25	34.7	46	32.4		
	Lower	51	70.0	4	5.6	55	38.2		
Soil Condition	Higher	68	94.4	35	48.6	103	71.5	40.3	0.000*
	Medium	3	4.2	32	44.4	35	24.3		
	Lower	1	1.4	5	6.9	6	4.2		
Inputs	Higher	8	11.1	5	6.9	13	9.0	2.9	0.24
	Medium	22	30.6	32	44.5	54	37.5	_	_
	Lower	42	58.3	35	48.6	77	53.5	_	_
Yield	Higher	56	81.9	10	13.9	69	47.9	71.1	0.000*
	Medium	9	12.5	18	25.0	27	18.8	_	_
	Lower	4	5.6	44	61.1	48	33.3		

*= significant at 5% probability level

4.4. Assessing the existences of Climate Chang in the study Area

In this section results to observe the existences of climate change at the study area was obtained through firstly by obtaining Climate data (Rain Fall and Temperature) from national Meteorology center of Ethiopia and for this rain fall and temperature trend analysis was done and secondly by conducting group discussion with key informants such as elder from each Kebeles, development agent and different officials and from focus group discussion(FGD) and this was analyzed using Crosstabs of descriptive statistics

4.4.1. Household's perception of climate change and variability

The results obtained from the survey, 98.6% of adopters and 93.1% of the non adopters households said that they heard about the word climate change in the study area, however 1.4% of adopters and 6.9% of non adopter households answered that they did not heard about the word climate change and variability in the study area (Table11). Concerning trend of temperature, 59.7% of adopters and 68.1% of non adopter households believed that the temperature of the study area was increasing over the past 30 years, whereas 37.5% of adopters and 23.6%of non adopter households believed that the temperature of the study area was fluctuating(Table11).

Regarding the experiences of households for the existences of climate change and variability indicators (such as drought, flood, frost/coolness and too little rain fall, etc) at the study area, 51.4% of adopters and 40.3% of the non-adopters respondents believed that there is drought, while 41.7% of adopters and 48.6% of non-adopters believed there is too little rain fall at the study area. Concerning the trends of rainfall over the past 30 years up to now 37.5% of adopters and non adopters agreed that there is fluctuation of rain fall, while 62.5% of adopters and 58.3% of non adopters believed that the rain fall is decreasing over the past 30 years (Table11).

Table 12: Households perception of climate change and variability

Variables		Practice CA (N=72		Do not practice CA (N=72)		Total (N=144)		X^2	P-Value
		N	%	N	%	N	%	5.331	0.149NS
Trend of temperature for the past 30 years	Fluctuating	27	37.5	17	23.6	44	30.6		
	Constant	1	1.4	5	5.9	6	4.2		
	Increasing	43	59.7	49	68.1	92	63.9		
	Decreasing	1	1.4	1	1.4	2	1.4		
Have you heard CC?	Yes	71	98.6	67	93.1	138	95.8	2.783	0.095NS
	No	1	1.4	5	6.9	6	4.2		
What are Climate change and variability indicators you have ever experienced?	Drought	37	51.4	29	40.3	66	45.8	2.164	0.539NS
	Flash Flood	3	4.2	4	4.6	7	4.9		
	Frost	2	2.8	4	5.6	6	4.2		
	Too little rain	30	41.7	35	48.6	65	45.1		
What were the trends of rainfall looks like over the past 30 years up to now?	Fluctuating	27	37.5	27	37.5	54	37.5	3.103	0.212NS
	Increasing	0	0.0	3	4.2	3	2.1		
	Decreasing	45	62.5	42	58.3	87	60.4		

*= Significance at 5% level

4.4.2. Observing Household's perception on Rain Fall variability in the study Area

Survey results in table14below indicated that 95.8%of adopters and 84.7% of non adopter's households believed that the rain fall is coming too late during the rainy season, whereas 2.8 %t of adopters and 15.3 % of the non adopter households replied that the rain fall is coming too early. 98.6 % of adopters and 88.9 %t of the respondents believed that there is too little rain fall at the beginning of rainy season but 1.4 % of adopters and 9.7 % of non adopters believed that there is much rain fall during rainy season. 94.4 % of adopters and 91.7 %of non adopters were agreed that there is too little Rain fall during growing season, whereas 4.2 % of adopters and 2.7 %of non adopters agreed that there is too much rain fall during growing season at the study area. 59. % of adopters and 68.1 % of non adopters believed that the rainfall is stopping on their field too early, but 36.1 % of the adopters and 22.2 %of non adopters believed that the rain fall is stopping too late. 98.6 % of adopters and 88.9 % of non adopters believed that there is Rain fall during the harvest time but 1.4 % of adopters and 11.1% of non adopters agreed that there is no rain fall during harvest time of their crop from field.

Table 13: Observing Rain fall variability in the study Area

Variable		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
		N	%	N	%	N	%	7.2	0.02*
Does rain fall coming on time?	On time	1	1.4	0	0.0	1	0.7		
	Too early	2	2.8	11	15.3	12	9.0		
	Too late	69	95.8	61	84.7	130	90.3		
Rain fall at begging of rainy season	enough	0	0.0	1	1.4	1	0.7	3.7	0.16
	too little	71	98.6	64	88.9	135	93.4		
	too much	1	1.4	7	9.7	8	5.6		
Rain fall during growing season	Enough	1	1.4	4	5.6	5	3.5	1.2	0.54
	Too little	68	94.4	66	91.7	134	93.0		
	Too much	3	4.2	2	2.7	5	3.5		
Does rain stop on your field on time?	On time	3	4.2	7	9.7	10	6.9	4.4	0.11
	Too early	43	59.7	49	68.1	92	63.9		
	Too late	26	36.1	16	22.2	42	29.2		
Rain fall during the harvest time	Yes	71	98.6	64	88.9	135	93.8	5.8	0.016*
	No	1	1.4	8	11.1	9	6.2		

*= significant at 5% probability level

4.4.3. Trends of Rainfall and Temperature (1987-2016).

Climate change is expected to create a serious risk on environment, agricultural production and food security of most developing countries including Ethiopia. The Ethiopian climate is characterized by great variation in different parts the country and a history of climate extremes such as drought and flood, and increasing and decreasing trends in temperature and precipitation is common in the Ethiopia.

4.4.3.1. Trends of Temperature in the study area (1987-2016)

The average yearly maximum temperature of the district was 30.7^{o}C, while the average minimum temperature of 17.628^{O}C. As it was showed in Figure 4, the maximum temperature of Loka Abaya district for the past 30 years was increased by about0.041^{o}C annually, while average minimum temperature is increased by 0.046^{o}C (Figure 4 and figure 5).This results in line with the survey result of respondent households concerning the increment of temperature for the past thirty years in the study area.

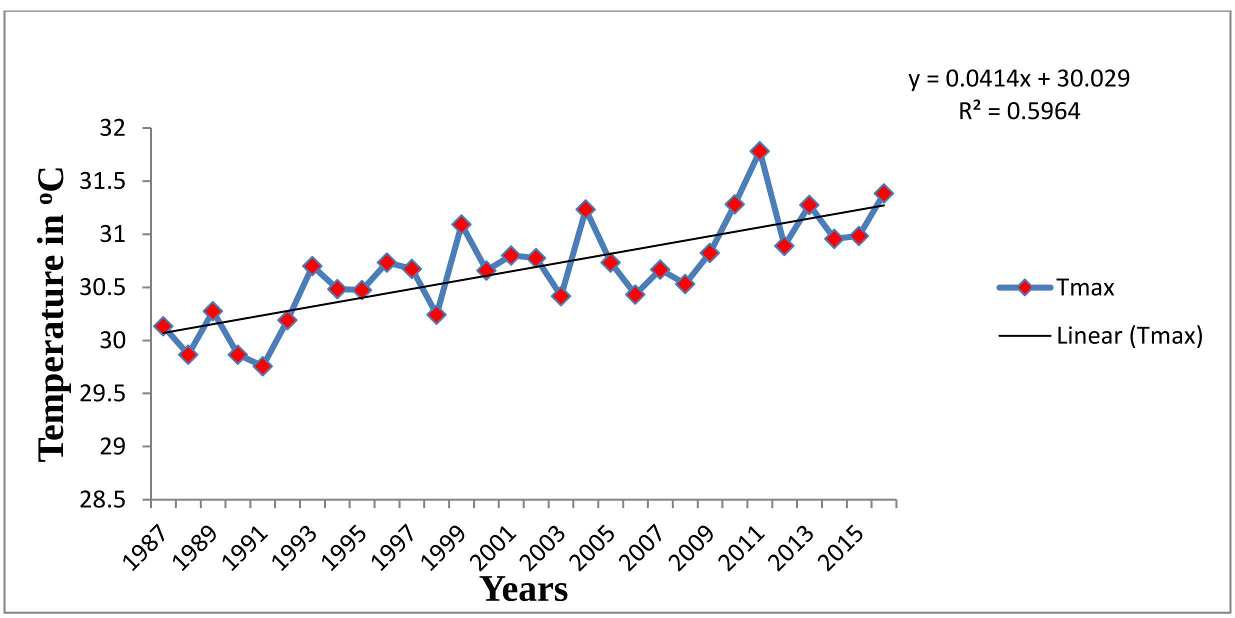


Figure 5: Trends of maximum temperature

Source: National Metrological Agency, Ethiopia (2017)

The trend analysis of Meteorological data record of temperature for the periods of (1987-2016) also indicated that there existed the increasing trend in annual maximum temperature over the past thirty years at the study area. The statistical record of temperature from Meteorological station was similar with the farmers‟ perception. In Ethiopia, temperature has been increasing annually at the rate of0.2°C over the past five e decades (Yohannes *al.*, 2009). According to the study of HDR (2007), the yearly time series of minimum and maximum temperature for 40 stations averaged over Ethiopia indicated a warming trend in temperature and it is clear that the average yearly minimum temperature is increasing much faster than the average annual maximum temperature.

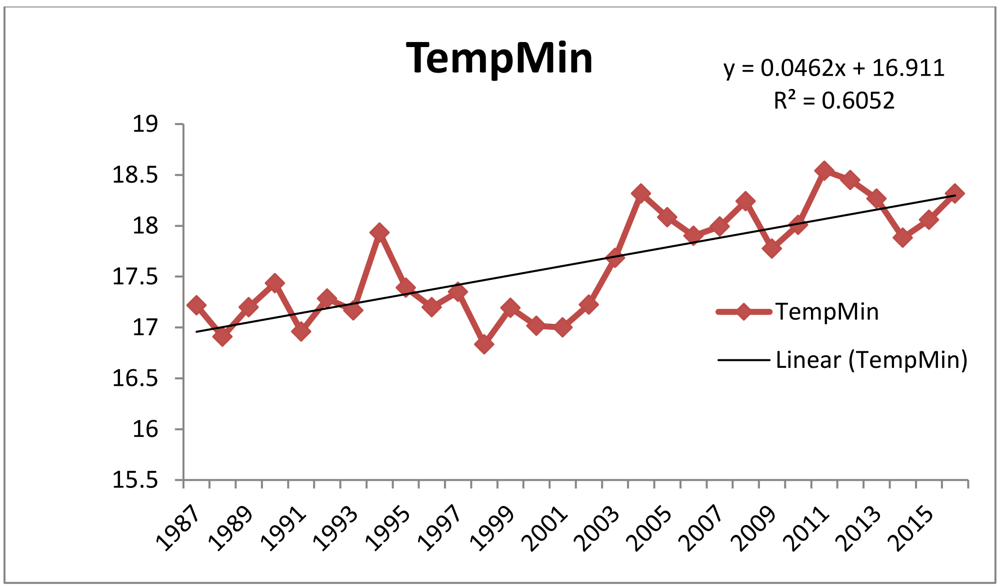


Figure 6:.Trends of minimum temperature (National Metrological Agency, Ethiopia (2016)

4.4.3.2. Trends of rain fall variability in the study area (1987-2016)

According to the data obtained from Ethiopia metrological Agency, the coefficient of variation of study area were 40, 32.5 and 23.3% for kiremt, belg and annual rainfall, respectively which indicate that there was high inter annual variability of rainfall between1987-2016. Degree of variation in amount of rainfall was higher for kiremt season than belg(Table 16).Various studies indicated that the trends in inter-annual and inter-seasonal rainfall variability like declining in amount, increasing in intensity and with increasing temperature are aggravating the rate of erosion, and consequently negative implication on crop and livestock productivity (Kassieet al.,2013)

Table 14: Coefficient of variance for annual, Kiremt and Belg rainfall (1987-2016)

Rainfall	Average rainfall (mm)	CV (%)
Annual	889.5	23.8
Kiremt	305.9	40
Belg	348.5	32.5

Source: National Metrology Agency of Ethiopia (2016)

The annual rain fall off the study area for the past 30 years was decreased by about 2.095 mm annually (Figure4 this result is also similar with the results confirmed by the respondents and according t the respondents perception on the trend of rainfall 60.4, 37.5 and 2.1% said rainfall was decreasing, fluctuating and increasing respectively.

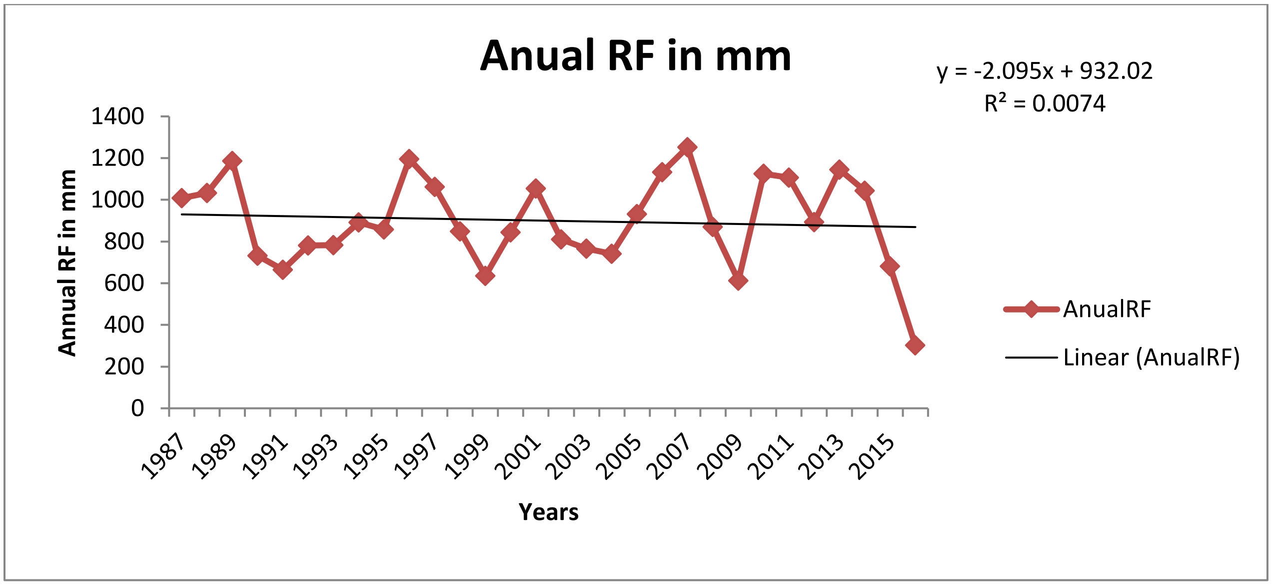


Figure 7: Trends of annual rainfall variability in the study area (National Metrological Agency, Ethiopia, 2016).

Based on the results of National Metrological Agency data, the Kiremt rainfall in the Loka Abaya district was increased by 1.546mm. But, trend line shows that about seventeen years the rainfall amount below average and thirteen years the amount of Kiremt rainfall above the average. In general it is believed that within these thirteen years there was high amount rainfall than the other seventeen years within thirty years.

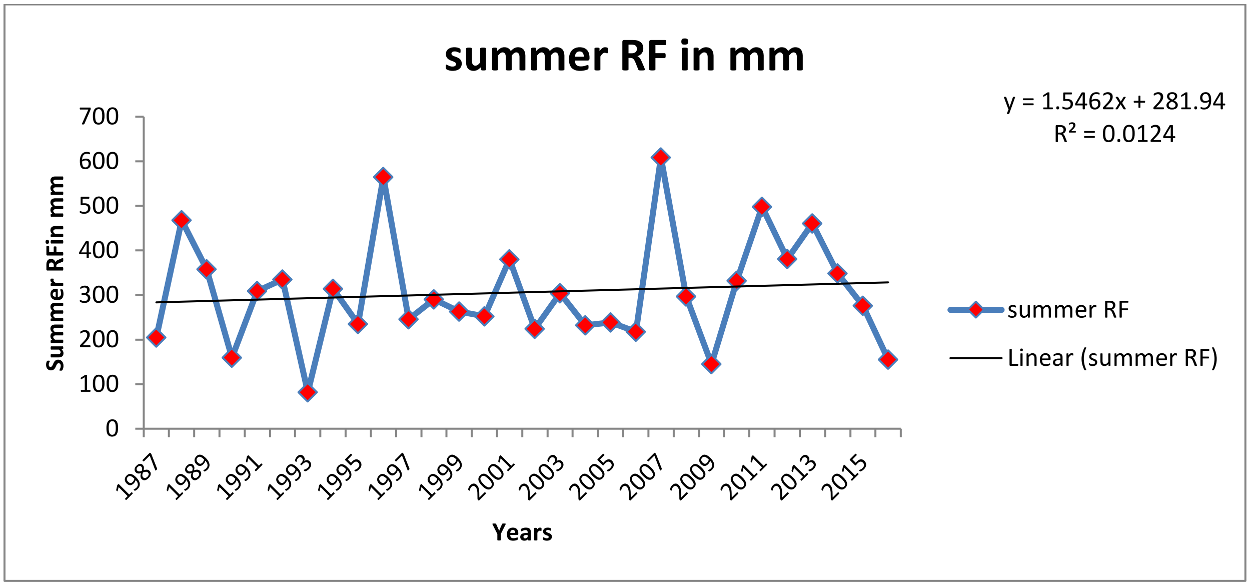


Figure 8: Trends of Kiremt rainfall (National Metrology Agency of Ethiopia, 2016)

Based on national meteorology data indicated in figure 5 below, the Belg rainfall in study area for the past 30 years was decreased by about2.356 mm. And this result was also similar with the results obtained from the survey on respondents, and therefore the trend of rainfall according to respondent's perception was 60.4, 37.5 and 2.1said fluctuating, decreasing and increasing, respectively.

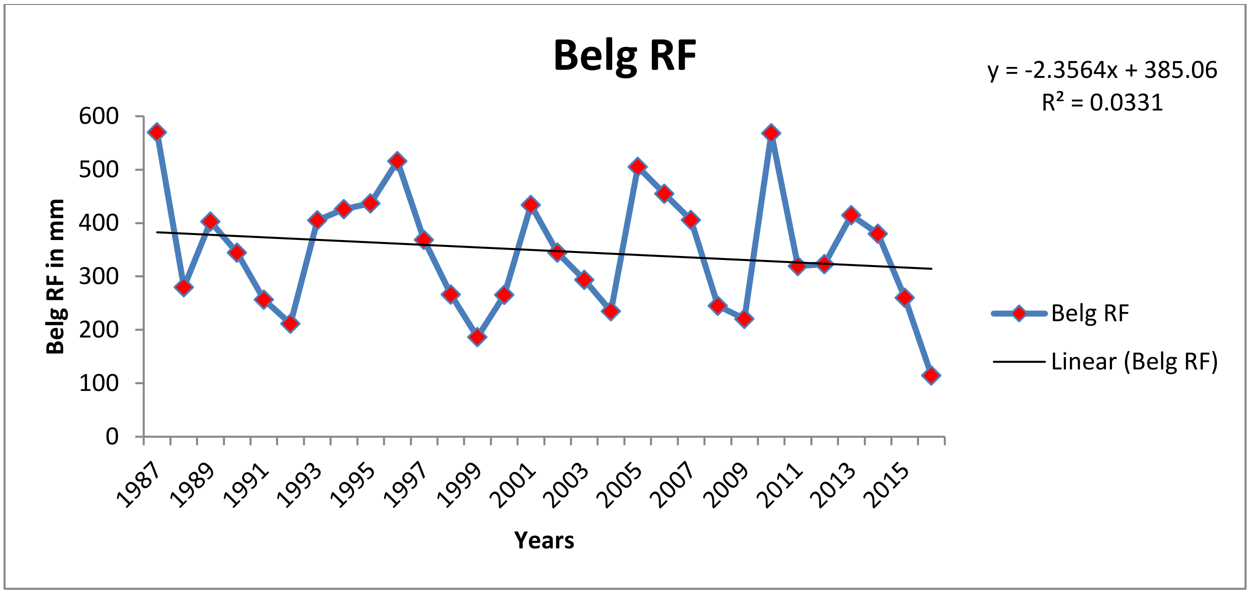


Figure 9: Trends of belg rainfall (National Metrological Agency, Ethiopia (2016)

The trend analysis of Meteorological data record of temperature period (1987 - 2016) also showed that there was increasing trend in yearly maximum temperature over the past thirty years. Thus, farmers‟ perception appears to be in accordance with the statistical record of temperature from Meteorological station. According to studies in Ethiopia, it is assumed that the temperature has been increasing annually at the rate of 0.2°C over the past five e decades (Yohannes *et al.*, 2009). The report of (HDR, 2007) indicated that, annual time series of minimum and maximum temperature for 40 stations averaged over Ethiopia reveals a warming trend in temperature and it is obvious that the average annual minimum temperature is increasing much faster than the average annual maximum temperature.

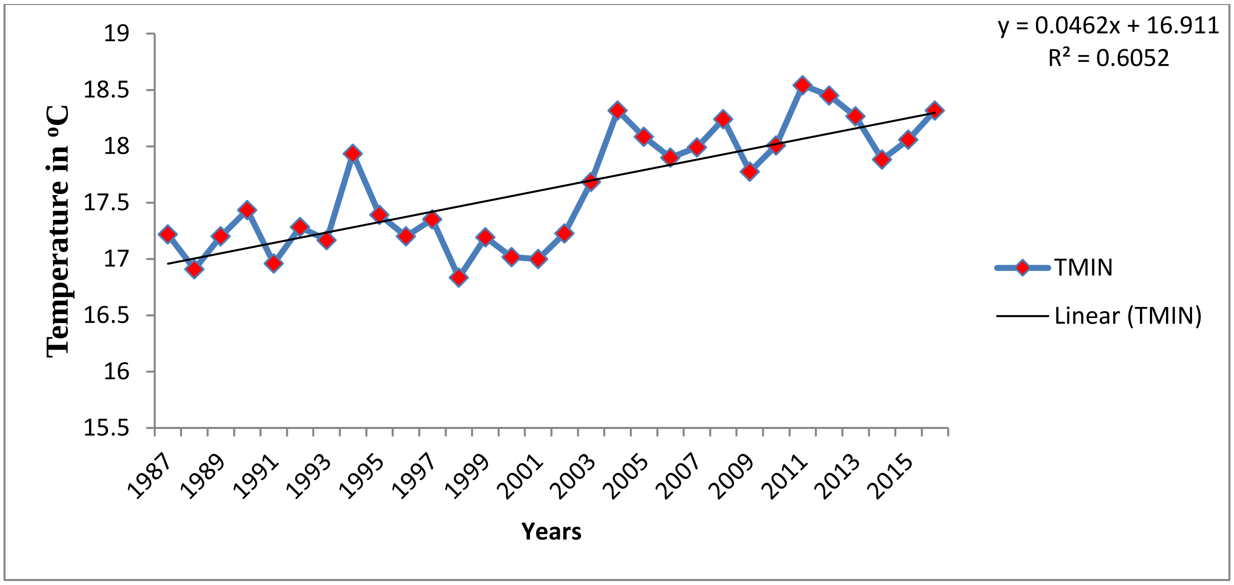


Figure 10: Trends of minimum temperature (National Metrological Agency Ethiopia, 2016)

4. 5.Assessing the role of CA to the Adaptation of Climate Change impacts

4.5.1. Comparative analysis of Household's Adaptation Status to the impacts of Climate Change

The results presented in Table 15 below indicated that, 51.1% of respondents perceived that CA reduced production cost, out of the total respondents, 93.1% of them were CA adopter households, while 11.1% of the households were non Adopters. On the other hand 6.9% of CA adopters and 88.9% non adopters perceived that CA did not reduce production cost. From this result we can understand that, CA technologies reduce production cost such as cost of fertilizer and labor and this was significant at 5% level. This result was similar with findings of (ECAF, 2012; Junior *et al*., 2012; Crabtree, 2010; Baig and Gamache, 2009; Bolliger *et al*., 2006), and which stated that once CA has become established on a farm, its lowered operating costs and the generally higher and more stable yields then begin to generate sufficient resources to pay the full commercial costs of the new inputs. But unexpected labor peaks can occur at harvest time due to increased yields from CA (Milder *et al.*, 2011). CA reduces costs associated with tillage, whether manual or by machinery (Richards *et al.*, 2014). According to Richardset al.(2014),in mechanized rice-wheat systems in India, field operational costs were 15% lower under CA. Conservation agriculture is a farming innovation that aims at producing high yields while reducing production costs, maintaining the soil fertility and conserving water (FAO, 2008).

The average labor employed by CA adopter and non adopters were 2.153 and 4.50 with the standard deviation 0.988 and 2.083 respectively and this indicated that, the labor used by CA adopters were lower than non CA adopters and this was significant at 5%level (Table 16).This result was in line with the findings of Richards et al. (2014), which stated that in manual maize systems in Malawi; CA fields required 20% less labor than conventional ridge and furrow fields. The reduction in field preparations with CA also allows timelier planting, which supports successful harvests. The water- and soil-conserving effects of CA help to stabilize yields against weather extremes. Often, CA increases average yields in the long term *(*Richards *et al.*, 2014)**.** Of the total interviewed households, 94.4% perceived that their conventional agriculture farm plots are more affected by climate change impacts such as erosion and flooding. In particular 91.7% of CA adaptors and 97.2% of non adopter's conventional plots are affected by the erosion, while only 8.3% CA adopters believed that their CA plots are affected by erosion. CA reduces soil erosion through reducing tillage and maintaining soil cover with crop residues and which can reduce soil erosion by up to 80%. CA also generally increases soil organic matter in topsoil, as well as soil biological activity and biodiversity.

Regarding the benefits of CA, the survey results indicated that there was significant differences between the group of adopters and non-adopters in that largely adopters perceived that conservation agriculture provide many benefit to adapt the impacts of climate change for the households in the study area. Results revealed that, 100% of adopters believed that CA had provided them many benefits during the time of climate change and these benefits include improved soil quality 8.3%, increased crop yield 2.8%, prevent erosion 12.5%, and improve soil health 1.4% and all the benefits listed above 75.0%. Similarly, 97.2% of the adopter and 25% of the non adopter households believed that CA enhanced soil moisture content, but 2.8% of adopters and 75.0% of non adopter households did not believe as conservation agriculture enhanced soil moisture content (Table 15). On the other hand, only 4.2% of non adopters of CA believed that, CA could increase the capacity to adapt to the impacts of climate change (Table15). From this result, we can understand that, conservation agriculture enhanced the capacity of adopter households than non adopters households to adapt the impact of climate change through building the capacity for their soil to hold moisture throughout the year and this in turn improve the crops resilience to the impacts of climate change during the dry season and which was significant at 5% level. This result is similar with the findings (Lanckriet *et al.*, 2012; Li *et al.*, 2011; Thierfelder and Wall, 2009, 2010; Govaerts *et al.*, 2009; Kassam *et al.*, 2009;) who stated that CA contributes many benefits to climate change adaptation and these benefits include less erosion possibilities, better water conservation, improvement in air quality due to less emission being produced, and a chance for larger biodiversity in a given area.

Likewise, from the total interviewed households, 54.2% believed that CA improves crop resiliencies to the impacts of climate changes. From these, the proportion of respondents were significantly different (93.1% of adopters and 15.3%of non adopters) of CA perceived that CA improved crop resiliencies to the impacts of climate changes (Table 15). From this result we can understand that most of CA adopters had a good perception about CA technologies as it improves the crop resilience to the impacts of climate change at the study area. These results were similar with the findings of Hobbs and Govaerts (2010), which stated that improved soil quality and improved nutrient cycling with CA will improve the resilience of crops to adapt to changes in local climate change while drought tolerance can be increased in some areas with CA.

Table 15: Contribution of CA on household to the adaptation Climate Change impacts

		Practice CA (N=72)		Do not practice CA (N=72)		Total sample (N=144)		X^2	P value
Variable		N	%	N	%	N	%	9.4	0.002*
Does CA reduce Production Cost?	Yes	68	94.4	55	76.4	123	85.4		
	No	4	5.6	17	23.4	21	14.6		
Do you use more labor on CA plot?	Yes	14	19.4	23	31.9	37	25.7	2.9	0.086
	No	58	80.6	58	68.1	107	74.3		
Plot more affected by erosion?	CA-plot	6	8.3	3	4.2	3	2.1	3.1	0.080
	CP –plot	66	91.7	69	95.8	141	97.9		
Benefits you obtained from CA?	Improve soil fertility	6	8.3	0	0.0	6	8.0	0.99	0.912
	Increase crop yield	2	2.8	0	0.0	2	2.7		
	Prevent erosion	9	12.5	0	0.0	9	12.0		
	Improve soil health	1	1.4	0	0.0	1	1.3		
	All	54	75.0	7	9.7	61	42.4		
Does CA enhance soil moisture saving?	Yes	70	97.2	64	88.9	134	93.1	3.9	0.049
	No	2	2.8	8	11.1	10	6.9		
Does CA improve crop resilience during CC?	Yes	67	93.1	11	15.3	78	54.2	87.7	0.000*
	No	5	6.9	61	84.7	66	45.8		

Table 16: Comparison of labor used by households

Variables	Group of respondents	N	Mean	Min	Max	SD	t-value	P-value
How much labor?	Practice CA	72	2.1528	1	10	0.98809	-11.498	0.000Sig
	Do not practice CA	72	5.81	1	12	2.27441		

4.6. Assessing the Contribution of CA on Household Food Security

In this section, the study assessed the contribution of CA on household food security, and this was done by running the comparative analysis of adopters and non-adopters household's food security indicators and maize yield data obtained from adopters and non adopter's households at the study area. This was done in two ways. The first way was dealt in this section and the second section was dealt in section 4.6.2.

Assumption

- The basic assumption in this study was that as both adopters and non-adopters households live and work in the similar area, any differences in each household food security status can be because of CA technology.

4.6. 1. Comparing the Indicators of Food Security between Adopters and Non-Adopters

The basic aim of this first section was to compare the basic indictors of Food Security between adopters and non adopter's households at the study area. The indicators include availability of enough food stock year round, number of times households feed per a day, comparing the amount of yield households obtained either from CA or non-CA plots during the time of climate change, comparing the importance of CA or non-CA in increasing households yield during the production period of 2016-2017.This study was mainly focused on the assessing the importance of CA on households Food security through assessing the availability of food in the household and this partly describe food security conditions at the study area. And also numbers of times household members taken meals per a day indicate the presence of food security condition.

According to the result obtained from the survey in table16, CA improves the existences of year round availability of food stock. Based on this 90.3% of CA adopter households and 34.7 % of non-CA adopters believed that, they have enough food stock year round and this difference was significant at 5% level. Similarly, 9.7% of adopters and 65.3% of non adopter households believed that they had no enough food to finish year and this is also significant at 5% level. It was again assumed in this study that, households who feed him/herself three or more than three times a day would be more food secure than those who feed him/herself less than three times a day do. According to the survey result in table16 below, 80.6% of adopters and 9.7% of non adopter households feed themselves more than three times per a day and this was significant at 5% level. Whereas 18.1% of adopter and 40.3% of non adopter households believed that they feed themselves three times per a day and 1.4% of adopters and 54.2% non adopter households feed themselves two times per a day. From these comparative analysis results of adopters and non adopters, we can understand that majority of conservation agriculture adopters feed themselves three or more than three times per a day and this was again significant at 5% level. This result was similar with the findings of Nymbose and Jumbe (2013) which stated that, households who had more year round maize yield availability and the prevalence of three times meals per a day under the CA adopter households were food secured. According to Nymbose and Jumbe (2013), adoption of CA had improved food security condition among small scale farmers.

General households who had above mentioned food security indicators (such as year round food stock availability, and number of meals they consumed per a day), are food secured. And also the households at the study area agreed that CA increased their yield more than non CA and they again believed that they were earning high amount of yield from CA farm at the time of erratic and unpredictable changes in climate. For these reasons, conservation agriculture improved the adopter household’s food security status at the study area by improving soil fertility, resulting in sustainable crop production, high retention of moisture in the soil because of adequate mulching, and reduced tillage, increased yield hence greater food security (African Conservation Tillage, 2005).

Table 17: Food security indicators of households

		Practice CA (N=72)		Do not practice CA(N=72)		Total sample(N=144)		X^2	P value
Food security Indicators		N	%	N	%	N	%	41.3	0.000*
Perception on CA in increasing yield?	More important	67	93.1	31	43.1	98	68.1		
	Less important	5	6.9	41	56.9	46	31.9		
Is CA increase yield more than CP?	More important	52	72.2	10	13.9	62	43.1	50.0	0.000*
	Less important	20	27.8	62	86.1	82	56.9		
More yield during CC impact?	From CA	30	41.7	0	0.0	30	20.8	21.3	0.000*
	From CP	42	58.3	72	100	114	79.1		
	From CA	65	90.3	0	0.0	65	45.1	1.1	0.000*
	From CP	7	9.7	72	100	79	54.9		
Number of times you feed per a day?	Two times	1	1.4	30	41.7	31	21.5	1.4	0.000*
	Three times	13	18.1	35	48.6	48	33.3	77.2	0.000*
	More than three times	58	80.6	7	9.7	65	45.1		
Food stock availability all the time?	Yes	65	90.3	25	34.7	90	62.5	47.4	0.000*
	No	7	9.7	47	65.3	54	37.5		

*= significant at 5% probability level

4.6.2. Econometrics model results

4.6.2.1. Estimated Results of Maize Production Functions for Adopters and Non-Adopter

In this the second way of assessing the role of Conservation agriculture on household's food security status at the study area, I estimated the maize production for both adopter and non adopter households of CA by using cob-Douglas production function by comparing the amount of yield obtained either from CA or non-CA plots during the time of climate change during 2016-2017 growing season.

For this estimation, the study used multiple linear regression analysis to obtain the values for the elasticity coefficients (βs) and estimate the results of maize production. Multiple regressions are a statistical technique that allows us to predict someone's score on one variable on the basis of their scores on several other variables.

In table 17, in a model summary, the "R" value is used to indicate the strength and direction of the relationship between the variables. The closer the value gets to 1, the stronger the relationship. In this case as shown below, R= 0.732. This means there was an overall strong and positive relationship between the variables. The R-Square in the study was found to be 0.563. This value indicates that the independent variables (Land size, improved seed, fertilizer, labor and Oxen draft power) can explain 56.3% of the variance in the Maize yield at Loka Abaya District. The remaining 43.7 % of the variance is explained by other variables not included in this study.

The estimated results in table17 below indicated that, the results for adopter households had positive relationship between total yield of maize and labor, seed, land, and draft access. This shows that as households at the study area employ more of these factors of production, there will be an increase in total output of maize yield. According to these results in Table 17 below, land, labor and seed had positive coefficients of elasticity among CA adopters. Based on this result, labor and land are the most significant factors of maize production among CA adopters. As more of these factors of production (land and labor) are used increasingly, there will exist more maize yield among the adopter households. The results of non adopter households indicated that, there is positive relationship between maize output and land, labor seed, fertilizer and draft access/oxen and again this implies that as the non adopter households employ more of these factors of production, there will be increase in the output of maize yield.

The coefficients of seed and drafting animals and seed for both adopters and non adopters and labor for non adopter households are not statistically significant in influencing maize production. This was due to that, majority of adopters and non adopter households use local seeds and also in case of land preparation time, majority of non adopter households use hand tools such as hoeing, picking, mattoking,…etc by using family labor instead of ploughing by draft animals. Due to this, the availability of draft animals and seed does not affect maize production at the study area.

The coefficient (β=0.615) of land for adopter household is statistical significant at 5% level. This indicated that, holding all other factors constant, an increase in land by one hectare will results in 61.5 percent increase in maize production. This result was similar with the findings of Nymbose and Jumbe (2013), which stated that, increase in land size and seed had positive and significant relationship between maize output and for non-adopters, land does not have any significant influence on maize production.

The mean Variance Inflating Factor (VIF) was 6.82 for adopters and 6.56 for non-adopters indicating no multicollinearity of these factors in the data collected since the VIF is less than 10 and this was in line with Hair, Anderson, Tatham and Black, 1995; Kennedy, 1992; Wasserman, and Kutner, 1989Marquardt, 1970).

Table 18: Maize Cob-Douglas production function for adopter and non-adopter households from Multiple Linear Regression analysis

	R	R Square			Adjusted R Square		Standard Error of estimate	Sig
Model Summary	0.732	0.536			0.500		2.762	0.000*

	Variables	CA-Adopters			Non-CA adopters		
		Standardized β	Std. Error	T-value	Standardized βs	Std. Error	T-value
	Constants	3.915	1.786	2.192	1.601	3.076	0.520
Coefficients	Land Size	0.615	3.870	5.431**	0.017	2.797	0.139
	Fertilizer	-0.031	0.012	-0.348	0.299	0.020	2.604**
	Labor	0.255	0.346	2.887**	0.155	0.183	1.150
	See(Kg)	0.161	0.193	1.475	0.342	0.115	2.678**
	Oxen(Draft access)	0.124	0.814	1.389	0.054	0.431	0.443
	RTS	**1.124**			**0.867**		
	VIF	**6.82**			**6.56**		

Source: Own estimation, 2017. *, ** indicates Significant at 1% and 5% probability level respectively.

Additional results in table above indicated that, the coefficient of fertilizer for CA adopters is negative and this negative and insignificant coefficient of fertilizer among CA adopters implies that adding inorganic fertilizer to the soils where there is CA is being practiced has no effect on maize production. These results enhance the chance for promoting CA technologies in order to minimize the cost of production at the same time improving soil health. This opposes results against non-adopters where maize production responds to increase in application of inorganic fertilizers.

The paper reveals that, fertilizer is a significant factor in the production of maize among non-adopters households of CA at 5% probability level and also keeping other things constant, if we increase fertilizer use by one kilogram for non-adopter households maize yield will increase by 33.2 percent.

For both adopters and non-adopters, land is an important factor of production in the study area. If farmer increases land size by one hectare, maize output will increase by 61.5 percent for adopters. Although increase in land responds high to maize output with 0.274 percent per hectare added for non-adopters, seed does not respond as much as compared to CA adopters.

Regarding the returns to scale (RTS), I was calculated it for both adopters and non adopter households using multiple linear regression analysis and these are the sum of coefficients of factors (inputs) of production. Returns to Scales are defined as a technical property of production that examines changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor (Stewart, 2008). As indicated in table above, the returns to scale for the adopter households was 1.0124 and which implies that, there was increasing returns to scale. This tells us that an equal and proportionate increase in all factors of production results in a greater and proportionate increase in maize production. This means that farmers have the potential to increase their production if they increase all factors of production proportionately.

Similarly, the returns to scale were calculated for non-adopters and were 0.867 which implies a decreasing returns to scale. Thus, an equal and proportionate increase in all factors of production results in less than proportionate increase in maize production. These results are in line with the findings by Kankwamba (2010) and Blessings et al. (2015) who confirmed that farmers can achieve increased returns to scale only if they use more of productive technologies like conservation agriculture and irrigation are intensified. Without these technologies, farmers have to improve efficiency at farm level, which is not the case most of times.

4.6.3. Comparing Maize Production for Adopters and Non-adopters of CA

The study compared maize production for both adopters and non adopters by using multiple linear regressions analysis. The analysis computed the mean maize production for both adopter and non-adopters of CA. The results suggest that the adopters have a higher mean maize production of 45.71 quintals as compared to that of non-adopter, which was 23.97 quintals (table17). The mean difference between adopters and non adopters was 45.56% indicating that maize production is better for CA adopters than non-adopters. The results are presented in the table below

Table 19: Average Maize production from multiple linear regression analysis

Condition	**Average production per hectare**	**Std.error**	**t-value**	**Sig.**	**95% Confidences interval**
Adopters	45.71quintals	2.76179	6.340	0.000	8.56-20.80
Non adopters	23.97 quintals	2.61915	6.340	0.000	8.50-16.55
%differences	45.56				

These results indicated that, CA has a greater role than non-CA in contributing maize production at the study area. Based on these findings, the basic message is that CA can be a much better solution in ensuring household food security than the promotion of chemical fertilizer use through programs under the changing climatic condition**.** This results were also similar with the findings of Pretty (1999) and Blessings et al. (2015) which stated that yields frequently increase substantially under CA, both in the first year and over time.

4.7. Assessing Determinants of the adoption of Conservation Agriculture

This section mainly focused on the variables that significantly affected households decision from adopting CA technologies at the study area were selected and used to be estimated by binary logistic regression model. As shown in Table21 at 4th step, the four variables namely advisory services households received from extension agents regarding CA, training of household on CA, household incentive for CA intervention and soil fertility status of their plots had been selected to have significant influence on the dependent variable i.e. adoption of CA.

Table 20: Likelihood estimate of the binary logistic regression model on Determinants of a CA adoption

Explanatory Variables		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Getting advisory services	5.231	.668	61.283	1	.000	187.000
	Constant	-8.034	1.114	51.976	1	.000	.000
Step 2[b]	Getting advisory services	3.132	.848	13.623	1	.000	22.909
	Training On CA	4.969	.828	36.039	1	.000	143.898
	Constant	-12.020	2.147	31.349	1	.000	.000
Step 3[c]	Getting advisory services	3.583	.981	13.327	1	.000	35.983
	Soil fertility status	1.813	.541	11.223	1	.001	6.126
	Training on CA	4.408	.931	22.441	1	.000	82.131
	constant	-15.289	2.901	27.786	1	.000	.000
Step 4[d]	Getting extension contact	3.209	1.130	8.067	1	.005	24.758
	Soil fertility status	1.945	.621	9.804	1	.002	6.996
	CA Incentives	3.051	1.167	6.839	1	.009	21.145
	Training On CA	4.466	1.147	15.161	1	.000	86.983
	Constant	-19.166	4.273	20.120	1	.000	.000

Variable(s) entered on step 1: Training on CA; Variable(s) entered on step 2: Advisor role; Variable(s) entered on step 3 soil fertility status.; Variable(s) entered on step 4: CA Incentives Where; S.E. =is Standard Error; Sig =is significance level; B= is Estimated Coefficient; df =is Degree of Freedom; Exp (B) =is Odds Ratio

4.7.1. Interpretation of Output from Binary Logistic Regression model

Based on the analysis obtained from binary logistic regression model, the results were interpreted as follows. The odds for CA adoption were 24.8 times higher in CA adopters who got advisory services compared to non adopter households of CA. The odds for CA adoption are 7.0 times higher in adopters whose soil fertility status was good compared to non adopter household. The odds for CA adoption are 21.1 times higher in CA adopters who got incentives compared to non adopters of Ca technologies. The odds for CA adoption is 86.9 times higher in CA adopters who got training on CA technologies compared to non adopters who did not got any training about CA technologies.

Getting advisory services to adopt CA technologies

Getting advisory service from extension agent was positive and significantly affected the likelihood of CA adoption decision of the farmers at the study area. This showed that households who got advisory service from development agents (DAs) are more likely adopted CA than who did not have advisory services. The results obtained from binary logistic model indicated that, the farmers who have got advisory service of extension agents adopted CA by a factor of 24.8times higher than the farmers who did not get advisory service. Depending on this result we can understand that advice of development agent workers and different technical support at individual farmer level has a great role by narrowing the knowledge gap of the farmers to adopt CA farming practices at the study area.

Importance of soil fertility to adopt CA technologies

According to the result obtained from the model, increase in soil fertility status of the farm was positive and significantly affected the likelihood of the adoption of CA by farmers at the study area. The results indicated that, households whose farm has more fertile soil adopted CA by a factor of 7.0 times higher than the farmers who did not have fertile soil on their farm. Based on this result we can understand that, increase in soil fertility provide conducive condition for the adoption of different CA technologies. When farmers started practicing the CA technology on a farm which has less fertile soil special at their first time, there might be reduction in the amount of yield for their crops and this can also be due to reduced amount of organic matter in the soil since amount of organic matter at the beginning stage is not that much. But when farmers started practicing CA farming system on fertile soil, they can get the increased yield for their crops since soil is already fertile and also practicing CA technology enhanced the soil fertility through addition of different crop residues and providing different cover crop. This increased yield facilitates the farmers to adopt CA technology quickly. This result was similar the findings of Frew (2016) and stated that, the farmers who have relatively more fertile land adopted CA technology than those who have less fertile land. This is probably due to farmers who have more fertile land are more interested on sustainable farming practices like CA than those farmers who have less fertile land.

Importance of incentives to adopt CA technologies

According to results of the binary logistic model, incentive in the form of different agricultural inputs positively and significantly affected the likelihood of CA adoption. The households who received incentives in the form of different agricultural inputs adopt CA by 21.145 times higher than the households who did not receive incentive at all when other independent variables remain constant. In other words, households who received incentive are likely to adopt CA by a factor of 21.145 times in comparison with who did not receive incentives. This indicate that, agricultural input incentive can enhances the level of adoption of CA by improving farmers' motivation and reducing farmers' fear on risk of technology failure. On the other hand, the price of agriculture inputs are increasing from time to time and it is not affordable for poor farmers to purchase the inputs for their conventional farms as well as farms for CA application.

Importance of Training on CA adoption

Based on result from binary logistic model above, training on different CA technologies components had positive and significant effect on CA technology adoption. The households who received training on CA technology components adopt CA by a factor of 86.983 times higher than those who did not received any training on CA technologies. This indicated that the farmers who received on full package of CA technologies have more knowledge and confidence than those farmers who received partially and less understood its principles. According to Progress (2012), training in CA significantly increased the likelihood of adoption of CA. This is because CA trainings were the most important source of information on CA practices.

Table 21: Classification Table

Variables		Predicted		Percentage Correct
		HH practicing CA		
		Adopter	Non adopter	
HH practicing CA	Adopter	70	2	97.2[3]
	Non-Adopter	2	69	95.8[2]
Overall Percentage				96.5[1]

1) 96.5percent of overall sample households were predicted correctly. So, the model shows us the prediction success at a 50% probability classification
2) 95.8 percent of non-adopters sample households were predicted correctly at a 50% probability classification.
3) 97.2 percent of CA adopter households were predicted correctly at a 50 % probability classification.

According to the results of the model in table above, 96.5 percent of overall sampled households were predicted correctly. This means that, 69 respondents out of 72 who did not adopt CA technologies and 70 respondents out of 72 who adopted CA technologies were predicted correctly. This showed that the model is a good fit of the data and predicts both groups of sample respondents properly. Therefore, the model adequately fits the data.

Table 22: Model Summary

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
30.242	0.692	0.922

Source: Binary logistic model

Nagelkerke R2 is an adjusted version of the Cox and Snell R-square that adjusts the scale of the statistic to cover the full range from 0 to 1 (Yoseph, 2014). **Cox and Snell's R^2** is based on the log likelihood for the model compared to the log likelihood for a baseline model. However, with categorical outcomes, it has a theoretical maximum value of less than 1, even for a "perfect" model. Depending on the results of binary logistic model, Nagelkerke R square .922 indicates that there were strong relationship of i.e. 92.2 percent between the independent variables and dependent variable. It means that the model could be 92.2 % explained by the aforementioned variables

Chi-square	df	Sig.
6.364	6	0.384

Source: Binary logistic model

Goodness of fit statistics help to determine whether the model adequately describes the data. The Hosmer-Lemeshow statistic indicates a poor fit if the significance value is less than 0.05 (Yoseph, 2014). But based on the survey result, the Hosmer and Lemeshow significance value (P=0.384) is not significant that shows the model is a quite a good fit to the data.

5. SUMMARY AND CONCLUSTIONS

This study assessed the roles of conservation agriculture on household's food security and climate change adaptation in Loka Abaya District of Sidama Zone, Southern Ethiopia. The socio-economic analysis from descriptive statistics revealed that mostly male-headed households irrespective of adoption status in general adopt and are practicing CA technologies in the study area. There is no significant different in age, family size, sex, farming experiences between adopters and non-adopters of the CA technology. However, there are positive and significant differences in the availability of household CA incentives, the number of years of schooling, and soil fertility status, access to CA training and access to extension contact. The factors influencing the probability of adoption of CA technology in the study area are accesses for CA training, level of education of the household head, access to extension services and household CA incentives. The percentage of farmer who received incentive and adopted CA technology was by far greater than the percentage of farmers who did not receive incentive.

Perception of respondents showed that the trends of rainfall and temperature are fluctuating and decreasing and increasing respectively. Regarding the trends of rainfall distribution according to respondent's perception, 30.6, 68.1 and 1.4% of them said, the rainfall was fluctuating, decreasing and increasing respectively and trends of temperature according to respondents' perception, 37.5%, 60.4%, and 2.1% of them said, it was fluctuating, increasing, decreasing respectively. The Metrology data analysis also shows the same as perceived by the respondents. In general, smallholder farmers in the study area perceived well about the two basic elements of climate temperature and precipitation trend over the past thirty years

A comparative analysis of food security between conservation agriculture adopters and non-adopters showed that there existed a positive relationship between CA adoption and achievement of food security condition in the study area. The results revealed that adoption of CA technology improved household's maize productivity by 45% than those who practiced conventional agriculture. Cobb-Douglas production estimates showed that CA adopters had more than 45% higher maize productivity than that of non-adopters. In addition, there were greater than proportionate unit increases in maize productivity with unit increase in land size and labor among CA adopters. The analysis of production elasticity's (coefficients) and the returns to scale have demonstrated that maize production among adopters increase with more than proportionate increase in input uses. The contribution of CA adoption on food security was also evident through farmers' report of increased number of meals per day and availability of food throughout the year among adopters.

Conservation agriculture improved the adaptation capacity for the households to the impacts of climate change at the study area. According to the reports of respondents, CA enhanced adaptation capacity for the impacts of climate change for adopter households than non adopter households by reducing production costs (such as costs of labor and chemical fertilizer) by 94.5%, reducing soil erosion by 80.6%, enhancing soil moisture saving capacity by 97.2%, increasing yield, soil fertility, improve soil health by 75%, improving crop resilience by 93.1%.

Regarding the benefits of CA, there were significant differences between the group of adopters and non-adopters in that largely adopters perceived that conservation agriculture provide many benefit to adapt the impacts of climate change for the households in the study area. All of the adopter's households believed that, CA had provided them many benefits during the time of climate change and these benefits include improved soil quality, increased crop yield, prevent erosion, and improve soil health by 75% and enhancing soil moisture saving capacity by 97.2%.

The results of binary logistic regression indicated that, training on different CA technology components, access to different extension services, and increased status of soil fertility and availability of different agricultural inputs in this case CA incentives had positive and significant effect on CA technology adoption. The households who received training on CA technology components adopted CA 86.983 % higher than those who did not receive any training on CA technologies. This indicated that the farmers who received full package of training on CA technologies have more knowledge and confidence than those farmers who received partially and less understood its principles. Household's who received incentive in the form of different agricultural inputs positively and significantly affected the likelihood of CA adoption. The households who received CA incentives in the form of different agricultural inputs adopt CA technology 21.14% higher than the households who did not receive incentive at all. Again, households who received different advisor roles for CA technologies from extension workers adopted CA technology 24.8 times higher than non adopters in the study area.

The recommendation of this study is that farmers' access to CA training services and access to different advisory services from extension workers, for farm households should be improved when promoting CA technology among smallholders in the study area. For these reasons, different non-governmental organizations (NGOs) and governmental organizations (GOs), planners and research institutes, who are working in promotion of different agricultural technologies such as CA would be recommended to provide training and demonstration to farmers which would help their ability in knowledge acquisition and quick understanding of technology components, consider incentive in terms of agricultural inputs to improve motivation of the farmers and reduce their fear on risk of technology failure. The study also recommends that, there should be dissemination of information about different CA technologies since majority of adopter households had more information about CA technologies than non-adopter households and due that the adopter households adopted CA technology. In order to provide information about the importance of CA technologies to households, there should be provision of media coverage at regional, zonal, district and even at Kebeles levels just like another agricultural technology. Again the study recommends that there should be creation of awareness for farmers about the importance of CA technologies for climate change adaptation. Majority of respondent perceived that trends of rainfall was highly fluctuating and decreasing in amount and very small numbers of respondents were perceived that trends of rainfall were increasing in the study area. And also majority of respondents perceived that a trend of temperature was fluctuating and increasing and very small amounts of respondents perceived that a trend of temperature was decreasing in the study area. Therefore, decreasing of rainfall distribution and increasing trends of temperature have negative effect on especial rain fed conventional agriculture with intensive tillage system in the study area. To cope up this decreasing and fluctuating condition of rainfall distribution and increasing temperature, the government should give due attention for the promotion and creation of awareness for the farm households about the importance of conservation agriculture systems since it increase the resilience for human or natural systems to the negative effects of climate change through preventing soil erosion, enhancing soil moisture saving capacity and improve soil health, and by improved soil quality, increased crop yield which in turn enhance the system to adapt to the impacts of climate change.

6. References

Adams JE. 1966 Influence of mulches on runoff, erosion, and soil moisture depletion. Soil SciSoc Am J 30:110–114

African Conservation Tillage Network (ACT). 2013. Introduction of conservation agriculture and agro forestry technologies into sustainable land management program (SLM II) in Ethiopia. Report submitted to World Bank County Office, Ethiopia. 92 p.

African Conservation Tillage. 2005. Conservation Agriculture Principles. Borrowdale, Harare, Zimbabwe

Apina, E.T. 2009. Conservation Agriculture Demonstration Guide. African Conservation Tillage Network. Nairobi.

Araya T, Cornelis WM, Nyssen J, Govaerts B, Getnet F, Bauer H, Amare K, Raes D, Haile M, Deckers J. 2012. Medium-term effects of conservation agriculture based cropping systems for sustainable soil and water management and crop productivity in the Ethiopianhighlands. Field Crops Res. 132:53-62.

Baker JM, TE Ochsner, RT Venterea and TJ Griffis. 2007 "Tillage and soil carbon sequestration—what do we really know?" Agric. Ecosyst. Environ. 118(1):1-5.

Barton AP, Fullen MA, Mitchell DJ, Hocking TJ, Liu L, Bo ZW, Zheng Y, Xia ZY. 2004. Effects of soil conservation measures on soil erosion rates and crop productivity on subtropical Ultisols in Yinnan Province. China AgrEcosyst Environ 104:343–357

Baudron, F., H.M. Mwanza, B. Triomphe, and M. Bwalya. 2007. Conservation agriculture in Zambia: a case study of Southern Province. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations, Paris.

Bewket W, Radeny M, and Mungai C. 2015. Agricultural Adaptation and Institutional Responses to Climate Change Vulnerability in Ethiopia. CCAFS Working Paper no.

106. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org pp15

Boahen, P. B.A., G.D. Dartey, E.A. Dogbe, B. Boadi, S. Triomphe, S. Daamgard-Larsen, and J. Ashburner. 2007. Conservation agriculture as practised in Ghana. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations, Paris.

CARE.2009a. Climate vulnerability and capacity analysis handbook. Online: http://www.careclimatechange.org/files/adaptation/CARE_CVCAHandbook.pdf.

Chivenge P, Murwira H, Giller K, Mapfumo P, Six J. 2007. Long-term impact of reduced tillage and residue management on soil carbon stabilization: implications for conservation agriculture on contrasting soils. Soil Till. Res. 94(2):328-337.

CSA (Centeral Statistical Authority). 2007. Central Statistical Authority population estimates in Ethiopia, Addis Ababa.

Choudhary MA, Lal R, Dick WA. 1997. Long-term tillage effects on runoff and soil erosion under simulated rainfall for a central Ohio soil. Soil Till Res 42:175–184

Clay DC, Byiringiro FU, Kangasniemi J, Reardon T, Sibomana B, Uwamariya L, Tardif-Douglin D. 1996. Promoting food security in Rwanda through sustainable agricultural productivity: Meeting the challenges of population pressure, land degradation, and poverty, Michigan State University, Department of Agricultural, Food, and Resource Economics.

Corsi et al., 2012.S.Corsi, T.Friedrich, A.Kassam, M. Pisante, J.C. de Moraes .Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: A litrature review, integrated crop management(101pp.) Vol16AGP/FAO,Rome 2012 development

Derpsch R. 2003. Conservation tillage, no-tillage and related technologies. Conservation agriculture, Springer: pp. 181-190

Dick, W.A., R.L. Blevins, W.W. Frye, S.E. Peters, D.R. Christenson, F.J. Pierce, and M.L.

Dimanche, P. H., 1997. Impacts de différentsitinéraires techniques dutravail du sol

Dumanski J, Peiretti R, Benetis J, McGarry D, Pieri C. 2006. The paradigm of conservation tillage. Proceedings of World Association

ECAF. 2001. *Conservation agriculture in Europe.*(www.ecaf.org/English/First.htm) Efficacité du semis direct à contrerl'érosionhydrique en milieu agricole :

FAO (Food and Agriculture Organization of the United Nations). 2009. Agriculture and Consumer Protection Department. Conservation Agriculture.Food and Agriculture Organization of the United Nations. http://www.fao.org/ ag/ca/.

FAO [Food and Agriculture Organization of the United Nations]. 2010a. Farming for the Future in Southern Africa: An Introduction to Conservation Agriculture. FAO Regional Emergency Office for Southern Africa, Technical Brief No. 01.

FAO [Food and Agriculture Organization of the United Nations]. 2010d. Cultivating Sustainable Livelihoods: Socioeconomic Impacts of Conservation Agriculture in Southern Africa. FAO Regional Emergency Office for Southern Africa, Technical Brief No. 2.

FAO [Food and Agriculture Organization of the United Nations]. 2010c. The Status of Conservation Agriculture in Southern Africa: Challenges and Opportunities for expansion. FAO Regional Emergency Office for Southern Africa, Technical Brief No. 03

FAO [Food and Agriculture Organization of the United Nations]. 2010b. “Climate-Smart” Agriculture. Technical input to The Hague Conference on Agriculture, Food Security and Climate Change, October 31-November 5, 2010. FAO, Rome.

FAO [Food and Agriculture Organization of the United Nations]. 2008. Investing in sustainable crop intensification: the case for improving soil health. International technical workshop, July 22-24, 2008, FAO, Rome.

FAO. 2011. The State of food and agriculture. Women in agriculture. Closing the gender gap for Govaerts, B., Sayre, K. D., Goudeseune, B., De Corte, P., Lichter, K., Dendooven, L. and Deckers, J. (2009) ‘Conservation agriculture as a sustainable option for the central Mexican highlands’, *Soil & Tillage Research*, vol 103, pp 222-230 group ii to the fourth assessment report of the intergovernmental panel on climate Change, M.L.

Fikiru, A.M. 2009. Assessment of Adoption behaviour of soil and water conservation practices in the Koka watershed, highlands of Ethiopia. M.Sc Thesis. Bahir Dar University, Bahir Dar. 62 p.

Food and Agriculture Organization of the United Nations, Agriculture and Consumer Protection Department, Conservation Agriculture. Available online: http://www.fao.org/ag/ca/ (accessed on 18 June 2015.

Forests.*Science* 318(5853): 1066–1068.

Friedrich T, Kassam A, Shaxson F. 2009. Agriculture for Developing Countries.Science and Technology Options Assessment (STOA) Project. Karlsruhe, Germany: European Technology Assessment Group.

Giller KE, Witter E, Corbeels M, Tittonell P.2009. Conservation agriculture and smallholder farming in Africa: the heretics’ view." Field crops research 114(1):23-34.

Girma.A and Merga.B. 2017. Experiences of Climate Resilient Sustainable Conservation Farming: the Case from Loka Abaya District, Sidama Zone; 1Hawassa University, College ofAgriculture, School of Plant and Horticultural

Sciences(*girmajibat2006@yahoo.com) 2Hawassa University, College of Agriculture, School of Animal and Range Sciences

Govaerts B, Sayre KD, Goudeseune B, De Corte P, Lichter K, Dendooven L, Deckers J. 2009. Conservation agriculture as a sustainable option for the central Mexican highlands.Soil Till. Res. 103(2):222-230.

Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre K, Dixon J, Dendooven L.2009. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. Crit. Rev. Plant Sci. 28(3):97-122.

Gujarati, D.N. 2004. Basic Econometrics. 4th edition. The McGraw-Hill Companies, New York. 1003 p.

Håkansson I.1994. Soil tillage for crop production and for protection of soil and environmental quality: a Scandinavian viewpoint. Soil and Till. Res. 30(2-4):109-124.

Harrington LW.2008. A brief history of conservation agriculture in Latin America, South Asia and Sub-Saharan Africa Conservation

Harrington LW .2008. A brief history of conservation agriculture in Latin America, South Asia and Sub-Saharan Africa Conservation Agriculture Newsletter PACA Lahmar R (2010) Adoption of conservation agriculture in Europe: Lessons of the KASSA project. Land Use Policy 27:4–10

HDR (Human Development Report), 2007. Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia. By IGAD Climate Prediction and Applications Centre (ICPAC).

Henderson, J. M. and Quandt, R. 1971. Microeconomic Theory, McGraw-Hill, New York, 106-113 pp

Hobbs PR, Govaerts B. 2010. How conservation agriculture can contribute to buffering climate change. Climate change and crop production 1.

Hobbs, P.R., K. Sayre, and R. Gupta. 2008. The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B 363: 543-555.

Hobbs, P. R. 2007. Conservation agriculture: what is it and why is it important for future sustainable food production? Journal of Agricultural Science 145: 127–137.Intergovernmental Panel on Climate Change. Cambridge, UK, and New York:

IPCC (Intergovernmental Panel on Climate Change). 2007a. Climate Change 2007: The Physical

IPCC (Intergovernmental Panel on Climate Change).2007b. Climate Change Impacts, Adaptation, and Vulnerability.Report of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, and New York: Cambridge University Press.

IPCC TAR WG1 2001. Houghton, J.T.; Ding, Y.; Griggs, D.J.; Noguer, M.; van der Linden, P.J.; Dai,X.; Maskell, K.; and Johnson, C.A., ed., Climate Change 2001: The Scientific Basis.Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

IPCC. 2007. Climate Change Impacts, adaptation and vulnerability. Contribution of working

Kassam A, Friedrich T, Shaxson F, Pretty J (2009). "The spread of conservation agriculture: justification, sustainability and uptake." Int. J. Agric. Sustain. 7(4):292-32

Kaumbutho, P., J. Kienzle (editors). 2007. Conservation agriculture as practiced in Kenya: two case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of theUnited Nations, Paris.

Knowler D, Bradshaw B. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy 32:25–48

Lal R. 1998. Mulching effects on runoff, soil erosion and crop response on alfisols in western Nigeria. J Sustain Agr 11:135–154

Lal, R. 2009. the plow and agricultural sustainability. *Journal of Sustainable Agriculture*, 33, 66–84.

Li L, Huang, Zhang R, Bill B, Guangdi L, Kwong YC. 2011. Benefits of Conservation Agriculture on Soil and Water Conservation and Its Progress in China. Agric. Sci. China 10(6):850-859.

Lobell, D.B., M.B. Burke, C. Tebanldi, M.D. Mastrandrea, W.P. Falcon, and R.L. Naylor. 2008. Prioritizing climate adaptation needs for food security in 2030. Science 319: 607-610.

Loka Abaya Agriculture Office (Loka Abaya WAO). 2017. Annual report of agricultural extension work process for 2016. Hantate, Ethiopia.

Loka Abaya Woreda Agriculture and Natural resource Development office.2012. Lokka Abaya Farm and Natural Resource Development office reports.

K. M. M. Rahman1, M. I. A. Mia2and M. K. J. Bhuiyan.2012. A Stochastic Frontier Approach to Model Technical Efficiency of Rice Farmers in Bangladesh: An Empirical Analysis 1Dept. of Agricultural Statistics and 2Dept. of Agricultural Business and Marketing, Faculty of Agricultural Economics and Rural Sociology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Mazvimavi, K., and S. Twomlow. 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agricultural Systems 101: 20-29.

McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, eds. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

Mohammed A, M Jaleta and E Berg, 2015. Adoption of multiple sustainable agricultural practices and its impact on household income: Evidence from Southern Ethiopia. Inter J AgriBiosci, 4(5): 196-205. www.ijagbio.com (©2015 IJAB. All rights reserved)

Marland, G., M. Obersteiner, and B. Schlamadinger. 2007. The Carbon Benefits of Fuels and

Melaku, J. 2015. Current states of Conservation Agriculture in Ethiopia: Sasakawa Global 2000 Ethiopia. Addis Ababa, Ethiopia. 15 p.Methods. Newbury Park, CA: Sage Publications.

Milder JC.Majaen T and Scherr SJ. 2011. Performance and Potential of Conservation Agriculture for Climate Change Adaptation and Mitigation in Sub-Saharan Africa. Final reports on an assessment of WWF and CARE projects in support of the WWF-CARE Alliance's Rural Futures Initiative. Cover images courtesy of EcoPortm (http://www.ecoport.org) : D. Lange and H. Smith pp 27

Mloza-Banda, H.R., and S.J. Nanthambwe. 2010. Conservation agriculture programmes and projects in Malawi: impacts and lessons. National Conservation Agriculture Task Force Secretariat, LandResources Conservation Department, Lilongwe, Malawi.

Morris NL, Miller PCH, Orson JH, Froud-Williams RJ.2010. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment—A review.Soil Till. Res. 108(1-2):1-15.

Moussadek, R., Mrabet, R., Zante, P., Lamachere, J-M., Pepin, Y., Le Bissonnais, Y.,

Mrabet R, Moussadek R, Fadlaoui A, Van Ranst E. 2012. Conservation agriculture in dry areas of Morocco. Field Crops Res. 132:84-94..

Natural Resources Conservation Service (USDA, NRCS), 1995.Soil quality. NRCS:RCA Issue Brief 5.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. and Kaltenborn, B. (eds). 2009. The Environmental Food Crisis. The environment's role in averting future food crises. A UNEP rapid response assessment. Arendal, UNDP

Nouira, A., Duchemin, M., Benmansour, M., Gallichand, J. and Bouksirate, H. 2007. Novembre 2007.Pp : 1-6.

Nyende, P., A. Nyakuni, J.P. Opio, and W. Odogola. 2007. Conservation agriculture: a Uganda case study. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of theUnited Nations, Paris.

Parry, M.L., Carter, T.R., Konijn, N.T. (Eds). 1998. The Impact of Climatic Variations on Agriculture, vol. 2. Kluwer, Dordrecht

RELMA[Regional Land Management Unit]. 2007. Wetting Africa's appetite: Conservation agriculture is turning rainfall into higher crop yields – and catching on. Review Series No. 3.

Ribeiro MFS, Denardin JE, Bianchini A, Ferreira R, Flores CA, Kliemann HJ, Kochhann RA, Mendes IC, Miranda GM, Montoya L, Nazareno N, Paz C, Peiretti R, Pillon CN, Scopel E, Skora NF. 2007. Comprehensive inventory and assessment of existing knowledge on sustainable agriculture in the Latin American platform of KASSA. In: Lahmar R, Arrue JL, Denardin JE, Gupta RK, Ribeiro MFF, de Tourdonnet S (eds) Knowledge Assessment and Sharing on Sustainable Agriculture. CIRAD, Montpellier, p 58

Richards.M, Sapkota.T, Sterling's, Thierfelder.C,Verhulst.N, Friedrich.T, Kienzle.J.2014. Conservation agriculture**:**Implementation guidance for policymakers and investors Science Basis. Contribution of Working Group I to the Fourth Assessment Report

Rockstrom J and Falkenmark M. 2000. Semi-arid crop production from a hydrological perspective - Gap between potential and actual yields. Critical Rev. Plant Science, 19(4):319-346.

Shetto, R. and M. Owenya (editors). 2007. Conservation agriculture as practised in Tanzania: three case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations, Paris.

Sidama Zone office of Finance and Economic Development Department (Sidama ZoFED).2014. Department of Data Collection and Dissemination Work Process. Hawassa, Ethiopia.

Singh B, Malhi SS (2006).Response of soil physical properties to tillage and residue management on two soils in a cool temperate environment. Soil Till. Res. 85(1-2):143-153.

Shah,M., Fisher, G. and van Velthuizen, H. 2008, Food security and Sustainable agriculture. The challenges of climate change in Sub Saharan Africa. Laxenberg: International Institute for Applied system analysis

Smit, B., Burton, I., Klein, R., Wandel, J. 2000. An anatomy of adaptation to climate change and Sustainable Food Production?*Journal of Agricultural Science* 145: 127–137.

Smit, B., Burton, I., Klein, R.J.T., Street, R., 1999. The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change 4, 199-213.sur la dégradation des sols argileuxdans la région de Meknès (Maroc).Thèse University Press, Cambridge, UK, 976pp.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. and Sirotenko. 2007. Agriculture. Pages 497-540 in Metz, B., O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (editors). Climate Change 2007, Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK and New York.

Thierfelder C, Wall PC. 2009. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil Till. Res. 105(2):217-227.

Thierfelder C and Wall P C 2010. Investigating Conservation Agriculture (CA) systems in Zambia and Zimbabwe to mitigate future effects of climate change. Journal of Crop Improvement 24: 113-121.

US Department of Agriculture, Washington Patton, M. Q. 1990. Qualitative Evaluation and Research

Varela AM 2001. Managing Agricultural Resources for Biodiversity Conservation.Case study Brazil, Cuba and Mexico. Study commissioned by ELCI, pp. 1-43. variability. Climatic Change 45, 223–251

Vitosh. 1998. Impacts of Agricultural Management Practices on Carbon Sequestration in Forest-Derived Soils of the Eastern Corn Belt. *Soil and Tillage Research* 47: 235–44.

www.fao.org/ag/ca/1a.html.

Wanangwa Nyambose & Charles B. L. Jumbe. 2013. Does Conservation Agriculture Enhance Household Food Security? Evidence from Smallholder Farmers in Nkhotakota in Malawi;

Ye, L., Verdoodt, A. and Van Ranst, E. 2011b. Influence du semis direct et

Yamane and Taro, 1967. Statistics: An Introductory Analysis. 2nd ed. New York, Harper

Yohannes G. Michael and Mebratu Kifle. 2009. Local innovation in climate change adaptation by Ethiopian pastoralists. PROLINNOVA- report, Addis Ababa, Ethiopia.

Yoseph, T.G. 2014. Software Based Statistical Methods for Scientific Research Training Module. 244 p.

APPENDICES

Table 1: Variance inflation factor (VIF) for Continuous Independent Variables

Continuous variables	VIF	Tolerance
Age	1.759	0.568
Family Size	1.422	0.703
Land Size	1.120	0.893
Farming Experiences	1.183	0.845

Source: own survey, 2017

Table: Contingency Coefficient (CC) for Categorical independent Variables

Variables	Sex	Marital status	Household incentives	CA training	Soil fertility	Education	Labor availability
Sex	1.000						
Marital Status	0.796	1.000					
Household Incentives	0.052	0.104	1.000				
CA Training	0.054	0.085	0.494	1.000			
Soil Fertility	0.122	0.123	0.366	0.519	1.000		
Education	0.309	0.311	0.322	0.424	0.422	1.000	
Labor availability	0.059	0.090	0.033	0.048	0.027	0.098	1.000

Source: Own survey, 2017

Table 3: Monthly Temperature (1987-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Min	Ave
1987	31.9	32.8	32.1	30.6	28.6	27.4	28.6	29.3	30.2	29.9	30.6	31.3	30.28	17.2	23.7
1988	32.2	32.8	33.7	31.2	28.7	28	26.4	27	28.2	29.1	30.2	30.9	29.87	17.4	23.7
1989	31.3	31.5	32.1	30	29.3	28.3	27.1	28.7	29.3	29.2	30.1	30.2	29.76	17	23.4
1990	31.6	30.8	30.7	30.7	29.8	28.9	28.1	28.1	30.5	30.8	31.5	30.8	30.19	17.3	23.7
1991	31.3	31.6	31.6	31.1	30.2	29.2	27.5	28.9	30.9	31.3	32.5	32.3	30.7	17.2	23.9
1992	33	32.7	33.3	32.1	30.4	29.3	28.8	27.9	29.2	28.9	30.2	30	30.48	17.9	24.2
1993	30.2	29.9	32.1	31	28.9	27.8	29.3	29.6	30.6	30.8	32.2	33.3	30.48	17.4	23.9
1994	33.9	34	33.2	31.5	29.1	28.2	27.7	27.7	30.7	31.2	30.4	31.2	30.73	17.2	24
1995	33.2	33.1	32.3	30.3	30	29.3	28.2	28.9	29.9	30.3	30.8	31.8	30.68	17.4	24
1996	31.9	32.8	32.2	31.2	28.9	28	28.1	28.1	28.8	30.1	31.1	31.7	30.24	16.8	23.5
1997	32.9	34.3	35.2	30.5	29.6	29.9	28.8	30.7	32.3	30.8	28.9	29.2	31.09	17.2	24.1
1998	31	31.8	32.4	32.6	30.3	30.1	28.5	28.2	30.2	29.6	31.1	32.1	30.66	17	23.8
1999	32.7	34.5	31.4	31.7	30.5	30	27.5	29.3	30.2	29.1	30.8	31.9	30.8	17	23.9
2000	33.3	34.7	34.8	32.2	28.8	28.5	28.3	27.9	30.5	29.1	30.1	31.1	30.78	17.2	24
2001	31.1	32.9	32.5	31	29.5	27.9	28.6	28.7	30.5	29.9	30.4	32	30.42	17.7	24.1
2002	31.5	33.9	32.3	31.6	29.8	29.7	30.1	29.8	31	31.1	32.8	31.2	31.23	18.3	24.8
2003	31.2	34.3	34.1	31.7	29.3	28.7	27.7	27.3	30.4	31.6	31.8	30.7	30.73	18.1	24.4
2004	31.7	32.2	34	30.2	30	29.3	29.1	28.9	30.4	30	29.8	29.6	30.43	17.9	24.3
2005	31.6	33.7	32.6	32.5	28.3	28.6	28	29.4	29.6	30.2	31	32.5	30.67	18	24.3
2006	33.9	33.7	31.6	30.1	29.9	29.4	28.8	28.6	30.3	30.5	29.8	29.8	30.53	18.2	24.4

2007	31.3	33.2	34	32.4	30.4	27.8	29	28	29.4	30.7	31.3	32.4	30.83	17.8	24.3
2008	33.6	33.8	34.9	32.4	31.2	29.6	28.4	29.7	30.4	29.8	29.8	31.8	31.28	18	24.6
2009	32.7	33.6	35	31.9	30.5	30.5	30.2	30.7	31.7	31.2	32.2	31.2	31.78	18.5	25.2
2010	32.3	32.9	31.8	31	29.4	29.3	28.6	28.7	30	31.4	32.7	32.6	30.89	18.5	24.7
2011	33.6	34.7	34.6	34.6	30.7	28.4	29	28.8	30	31.1	29.6	30.2	31.28	18.3	24.7
2012	33.2	34.5	34.8	31.1	29.8	28.2	28.2	29	29.4	30.6	30.7	32	30.96	17.9	24.4
2013	32.9	35.2	33.1	30.9	30.1	29.4	28.9	29.4	30.9	30.5	28.9	31.6	30.98	18.1	24.5
2014	33.6	33.3	33.6	32.7	31.1	29.7	29.3	30.2	29.9	30.2	31.2	31.8	31.38	18.3	24.9
2015	31.7	32.4	34.2	32.3	29.4	28.4	28.2	28	30.4	30.8	31.5	31.8	30.76	18.3	24.3
2016	33.2	33.5	33.8	31.6	28.9	28.7	28	29.4	30.2	31	28.9	31.2	30.7	17.8	23.8

Source: National Meteorological agency of Ethiopia, 2016

Table 4: Monthly total Rain Fall (1987-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	17.9	14.2	155.7	168.4	245.7	19.6	15.4	55.8	114.2	136.7	50.7	14.4
1988	6.1	26.2	43.6	151.3	85.3	48.6	153.1	139.2	126.6	169.6	67.6	15.4
1989	34.1	44.2	94	178.7	130.2	102	121.5	57.2	77.3	126.4	83.4	136.6
1990	4.7	126.7	122.7	81	141	35.1	23.3	48.7	52.4	44.8	26.7	25
1991	23.5	40	109.1	28.1	119.3	63.8	65.5	76.6	103.1	24.7	5.4	6
1992	8.4	0	20.8	133.6	57.1	44.1	84.5	84.4	121.6	166	25.4	35.5
1993	82	138.7	15.3	165.6	224.4	57.5	0	24.1	0	56.3	18.7	0
1994	0	5.3	58.6	162.2	205.4	76.1	85.5	103.6	48.5	61.6	73.3	10.9
1995	0	28.6	79.1	217.4	140.5	52.5	62.7	35.2	84.4	94.9	43.2	19
1996	17.4	5.3	112.7	247.9	155.6	161	102.5	193.6	107.3	54.6	31.7	6
1997	3.4	0	20	217.7	131.1	60	86.2	65.4	34	216.9	166.6	61.1
1998	58.2	41.7	48.9	117.6	99.5	69.4	79	112.1	29.8	169.3	22.6	0.4
1999	10.2	0	85	62.2	39.2	52.8	95.9	67.3	46.7	144.6	15.1	16.1
2000	0	0	10.1	93.9	161.5	56.6	82.3	74.6	38.6	212.1	86.5	27.8
2001	27.5	15.1	130.5	150.5	152.9	80.6	130.5	98.8	70.1	139	49.6	8.6
2002	32.5	16.9	179.4	133.4	32.1	69.4	45	63.9	45.9	66.9	19.9	104.1
2003	10.5	6.7	33.6	163.2	96.7	56.1	79.5	145.6	22.4	44.6	52.3	55.1
2004	43.9	27.1	13.1	164.2	57.7	41.7	29.9	78.8	81.9	53.2	102	47.7
2005	16.4	8	107.3	150.1	247.7	45.1	84.4	20.6	88.5	132	31.1	0
2006	13.8	45.8	155.3	174.5	125.1	60.1	40.6	111.9	5.2	170	103.5	126.6

2007	67.9	22.9	72.9	132.4	200.5	163.1	105.1	185.1	155.4	98.6	48.5	0
2008	7.8	5.6	35.8	114.6	94.9	34.7	97.2	79	85.7	202.6	112.4	0
2009	0	11.9	15.3	90.8	114.6	44.4	18.4	28.6	53.5	153.3	35.1	45.6
2010	34.9	70.8	191	183.2	194.1	108.9	55.1	92.3	75.8	91.9	8.7	18
2011	0	11.9	31.8	49.2	238.3	145.6	115.5	124.7	112.4	66.6	210.3	0
2012	0	0	10.6	211.1	101.1	48.8	112.1	112.5	107.6	90.8	68.1	30.2
2013	17.7	12.6	75.6	181.3	157.9	71.3	98.8	129.1	161	157.5	77.8	3.9
2014	6.2	45.9	104.8	72.2	203.2	61.8	64.7	136.6	85.5	176.2	86.8	0
2015	14.3	6.7	70.9	87.8	101.2	40.8	97.1	65.7	72.5	92.4	31.7	0
2016	0	0	13.8	48.5	52.4	32.6	16.4	101.4	5.1	22.8	7.7	0.8

Source: National Meteorological agency of Ethiopia, 2016

Household-Level Survey Questionnaire for the Research on the roles of Conservation Agriculture on Food Security, Climate Change Adaptation and Mitigation: Study of Lokka Abaya District, Sidama Zone

Basic Information

Region Name: SNNPR Zone Name: Sidama District Name: Loka Abaya Name of Village (Kebeles): ______________________________________

Name of Interviewer: ____

Name of Household Head: ____

Name of the Respondent: ____

Household Code (ID): ____

Instruction: Dear enumerator, please circle the number representing respondent's answer from given alternatives for each part and or write their answer for the rest of questions requiring quantitative and other responses

Part 1: Socioeconomic Background

1. Age of the respondent **(**in years) ______________________

2. Sex of respondent: (1) Male ____________ (2) Female _________________

3. Marital status of the household: (1) Single______ (2) Married______ (3) Divorced______ (4) _______Widowed

4. Household structure 1. Male headed __________ 2. Female headed_______

5. *Family si*ze/Household size: Male _________ Female _______Total_________

6. Education level of the household head: (in number of schooling years) _____

7. Farming experience of the household head (in years) _______

8. Religion: 1. Christian ___________ Muslim____________3.None__________

Part 2: Socio-economic Characteristics

Landholding

8. Do you have your own land? 1) Yes_______ 2) No ________

9. Land holding characteristics of the respondents

Plot No.	Plot size in ha	Distance from home/hr/min	Soil fertility status
1			
2			
3			

For soil fertility condition 1= more fertile 2= moderate and 3 = less fertile

Livestock ownership and feed availability

10. Do you have livestock? 1) Yes__________ 2) No _______ (if the HH say no to this question, just pass to question #16)

11. If numbers of domestic animals owned by the households during the survey time

Types of domestic animals	Unit	Total no. of domestic animals	local	Improved	Remark
Cow	No.				
Bull	No.				
Ox	No.				
Calf	No.				
Heifer	No.				
Sheep	No.				
Donkey	No.				
goat	No.				
Chicken	No.				
Horse	No.				
Total					

Feed Availability:

12. What do you feed your livestock?

1) Crop residue: a) cereal______b) Legume _______c). _________both

2) Green forage _______3) Furishika______ 4) Grazing land______a. Individual ____b Communal ___________5) Letting them in to farm land after harvest_________

Labour availability:

13. Can you get the labour easily if you want to hire for farming? 1. Yes ___ 2.No _____

14. How many labor do you employ on your farm per a season? (Mention in number) Male_____ Female_______ Total___________

Incentive:

15. Do you get incentive for Adopting Conservation Agriculture technology? Yes 2. No

16. If yes, what do you get as incentive? 1=Fertilizer 2= Herbicide 3= Seed 4= CA Equipment or farm tools 5 =all 6) one and three 7) two and three 8) 1,2 & 3 9) 2, 3 & 4

Part 3. CA Technology related characteristics

Food Security Condition of a Household

17. What is your Perception about CA technology in terms of improving food security by increasing your yield? 1= More important, 2=less important

18. In your opinion, is it more important than conventional/traditional agriculture in increasing yield? 1. More important___________ 2. Less important_______________

19. If you compare the yield you obtain from CA and non CA, which one is greater?

1. CA__________ 2 .CP_________________

20. During the time of climate change impacts (drought, intensive flooding), from which plot of the farm you get more yield? 1. From CA 2. From CP___________

21. How many times do you feed yourself per a day? 1. Two times______ 2. Three times____ 3. Four times____ 4. More than four times____

22. Does your household have food stock available all the time for consumption?

1. Yes 2. No

Observing Climate change

23. Have you ever heard the word climate change before 30 yrs?

1. Yes 2. No

24. What are climate change and variability indicators that you have ever experienced?

1. Drought 2. Flood 3. Frost 4. Too little rain 5. Intensive rain fall

25. What was trend of temperature for the past 30 years to date?

1. Fluctuating 2. Constant 3. Decreasing 4. Increasing

26. What were the Trends of rainfall looks like for the past 30 years up to now?

1. Fluctuating 2. Increasing 3. Decreasing

27. Does the rainfall coming on time? 1. on time 2. Too early 3. Too late

28. Is there enough rain on your fields at the beginning of the rainy seasons?

1. Enough 2. Too little 3. Too much

29. Is there enough rain on your fields during the growing seasons?

1. Enough 2. Too little 3. Too much

30. Does the rains stopping on time on your fields? 1). on time 2) Too early 3) Too late

31. Is it raining during the harvest time? 1. Yes 2. No

Adaptation status of household to the impacts of Climate Change

32. In practicing CA, do you think that it reduce the production cost? 1. Yes_ 2 .No______

33. Do you use more labor when you practice CA? 1= Yes 2= No

34. Which of your farm plot is more affected during the erosion? 1= CA 2= CP

35. What are the benefits that you get when practicing CA technologies?

A) It improved our soil fertility B) It increased our crop yield

C) It prevented our soil from erosion

D) Improved soil health especially soil organisms revived

E. All

36. Does conservation Agriculture enhance soil moisture holding capacity than conventional agriculture?

1= Yes 2= No

37. Does Conservation Agriculture improves the resiliencies of crops during climate change impacts (such as flood, erosion, etc)?

1= Yes 2=No

Conservation Agriculture Technology Adoption status of the household

38. Do you practice CA? 1= Yes 2= NO

39. What are factors that affected your ability from adopting CA technologies?

A. Land size B) Input shortage C) Experiences D) Labor shortage E) Gender

40. What are challenges that you encountering/encountered in CA?

1) Shortage of herbicide 2) Shortage of herbicide sprayer 3) Not getting fertilizer with the seeds 4) Misunderstanding of fellow farmers 5) Difficult in hand weeding 6) not getting enough advisory role from extension workers 7) infestation by pest 8) Scarcity of crop residue

41. Which parts were Difficult in CA**?** 1) Minimum tillage 2) Crop rotation 3) Weed management 4) Permanent crop cover/residue 5) no difficult part at all

42. If your answer is No for Q#37, why you not practice it?

1) Shortage of land 2) lack of understanding 3) Unavailability of required seeds 4) Fear of bearing risk for new variety

43. In your opinion, is it worth buying herbicide than hand weeding? 1= Yes 2= No

44. What is your perception on CA technology over conventional agriculture? 1= Good 2= Bad

45. Do you need more information about CA technology? 1= Yes 2= No

46. If yes, how much information you seek to know about CA technology?

3. All information_____ 2. Some information______ 1.little______

Compatibility:

47. Do you think that conservation agriculture technologies are compatible with existing farming system of your locality? 1=yes, 2 =No

48. If your answer is 'Yes' for Q#31, in what farming system is it compatible?

A. Hoe culture___________, B. limited oxen plow_________________

C. Soil type suitability__________ D. Dry condition(hotness) ___________

Trial ability:

49. Do you think that it is easy to experiment / try the CA technology in small part of your farm land? 1=yes, 2=No

Part 4. Institutional Characteristics

CA Training and its practice:

50. Have you heard about conservation agriculture technology?

1. Yes 2. No

51. What is the length of time since you first heard about CA technology?

1) Less than two years 2) Two years 3) Greater than two years 4) Greater than or equal to three years

52. Have you ever received training on conservation agriculture technology? 1=Yes 2=No

53. If yes to question # 35, what were the topics covered? 1) All CA components were covered 2) CA components partly covered

54. Are you practicing CA for at least two years?

A) Yes B) No

55. Have you ever create bed and furrows before sowing your crop?

1) Yes 2) No

56. Do you plough the bed/farm 1) Yes 2) No

57. For conventional tillage, how many times do you plough bed/farm?

1) One time 2) two times3) three times 4) four times

58. Do you plough the furrows? 1) Yes 2) No

59. If yes, how many times per year? 1) One times 2) two times 3) three times 4) four times

60. Have you ever living crop residue on your farm? 1) Yes 2) no

61. If your answer is yes, why you are living?

1) Increase Soil fertility 2) Soil Moisture saving 3) decrease soil erosion 4) To get better yield 5) all except four 6) 1 and 3 7) all

62. If no, why not living crop residue? 1) Use as Fodder for animals 2) Use as fire wood 3) Used for construction of houses 4) all except three 5) all

63. Do you use crop rotation?

1) Yes 2) no

64. If yes, why you practice it? 1) Increase soil fertility and crop yield 2) Effective Nutrient utilization 3) To break life cycle of weeds, diseases and pests 4) one and three 5) all

65. If no, why not practice it? 1) Shortage of land 2) lack of understanding 3) Unavailability of required seeds 4) Fear of bearing risk for new variety

66. How do you control the weeds? 1) Hand picking 2) using herbicide 3) both

67. Compare CA with traditional farming system for questions1-5 below and put your choices for each type of farming system: 1) Higher 2) Medium 3) lower)

No	Conditions	CA	Conventional Agriculture/CP
1	Weed population		
2	Soil condition		
3	Input		
4	Labor		
5	Yield		

68. How do you control the weeds? (MeansWeedContrl)

1) Hand picking 2) using herbicide 3) both

69. Which inputs challenges from adopting CA TECHNOLOGIES?

A) Fertilizer B) Selected seed C) Herbicides D) Crop residues E) All

1: Checklist for Focus Group Discussion (FGD)

A. Roles of conservation agriculture on food security and climate change adaptation

1. Do you think CA enhances household's food security at Loka Abaya?

2. Do you know if there are plans or initiatives to promote CA technology systems in the study area?

3. Do you think CA contributes of climate change adaptation in the study area?

4. Is there any food insecurity condition at your area? How you explain it in relation with climate change?

5. Is CA important in improving food security at you locality?

6. If you compare yield of CA with no-CA, which one is greater?

B. Climate change assessment

1. Do you know the meaning of climate change?

2. Is the pattern of weather is changing?

3. How do you explain the change?

4. What would be the cause?

5. In the past 30 years how would you describe the rainfall pattern in terms of -

I. Rainfall on-set and Cessation

ii. Rainfall amount

iii. Rainfall seasonal distribution.

iv. Temperature

6. What is the manifestation of climate change at Loka Abaya?

7. Are flood, drought, high temperature, too little rainfall, and frost frequently occurring at your locality?

8. Has it impact on agricultural practice? Could you tell us the major impacts that you perceived?

BIOGRAPHICAL SKETCH

The author, Yohannes Batiso, was born on April 03, 1988 from his father Batiso Urago and his mother Kafale Barasa in Boricha District, Sidama Zone, Ethiopia. He attended his elementary school in Yirba Yanase Primary School and attended his secondary School in Leku and his preparatory school in Hawassa Tabor Secondary and Preparatory School. Soon after completing his preparatory school in May 2008, the author was joined Hawassa University, College of Agriculture, and Department of Agricultural Resources Economics and Management since October 2009; and graduated with B.Sc. degree in July 2011.

Following his graduation he was employed by Boricha Woreda agricultural office. After three year work experience he joined Hawassa University, School of graduate studies in 2015/16 academic year. He is married.