ADDIS ABABA UNIVERSITY
COLLEGE OF DEVELOPMENT STUDIES
ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

ADOPTION OF CLIMATE SMART AGRICULTURAL PRACTICES: DETERMINANTS AND CHALLENGES IN GERAR JARSO WOREDA OF OROMIA REGIONAL STATE, ETHIOPIA

BY
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A Thesis Submitted to the College of Development Studies of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Master of Arts in Environment and Sustainable Development

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DECLARATION

I, the undersigned, declare that this thesis work is my original work carried out by me. All the resources and materials used for this thesis have been fully acknowledged.

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THESIS APPROVAL
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This is to certify that the thesis prepared by Tewodros Beyene , entitled: *Adoption of Climate Smart Agricultural Practices: Determinants and Challenges in Gerar Jarso Woreda of Oromia Regional State*, *Ethiopia* and submitted in partial fulfilment of the requirement for the degree of master of arts (Environment and sustainable development) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Adoption of Climate Smart Agricultural Practices: Determinants and Challenges in Gerar Jarso Woreda of Oromia Regional State, Ethiopia

Abstract

Ethiopia's low level of economic development with its heavy dependence on rain- fed agriculture, which is the sector most vulnerable to climate change make the country susceptible to the adverse effects of climate change. To counter this, several measures have been suggested in attempts to reduce the vulnerability of smallholder farmers who are the worst affected by changes in climate. One such intervention is climate smart agriculture (CSA), which is probably one of the most viable and sustainable option. It offers triple wins; Mitigation and adaptation measures to climate changes and sustainably increasing agricultural productivity and incomes. However, the adoption of climate smart agricultural practices is far below the expectation. Thus, this thesis answers why some farmers practice it while others not. To address this general question a study was conducted with objective to examine factors affecting adoption of climate smart agricultural practices in Gerar Jarso woreda of Oromia region. Mixed research method design was employed in order to conduct this study. Household questionnaire survey (N=201), focus group discussion, key informant interview and field observation were used to collect data. Logistic regression model was employed to identify key factors that influence adoption of climate smart agricultural practices. The result showed that sex of household heads, education level of household heads, off-farm income , livestock number , farmers' field day participation, knowledge on environmental regulation , access to extension services and being member of organizations were positively correlated and significantly determine adoption of CSA practices. Therefore, the findings of the promising demographic , socio-economic, and institutional factors should be given to capitalize by the Woreda Agriculture and natural resource development office and other concerned bodies to enhance farmers' adoption potentials of the study area. Moreover, before expanding CSA practices in other areas of Ethiopia, addressing the implementing obstacles by establishing enabling local environments through enhancing farmers' implementing capacities and incentives to implement is crucial.

Keywords: *Adoption, Climate change, Climate smart agriculture, Determinants, Gerar Jarso*

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ACRONYMS AND ABBREVIATIONS

ACSAA	Africa Climate-Smart Agriculture Alliance
AGP	Agricultural Growth Programme
CASCAPE	Capacity Building for Scaling up of Evidence –Based Best Practices in Agricultural Production in Ethiopia
CBD	Convention on Biological Diversity
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
CSA	Climate-smart agriculture
DA	Development Agents
ENMA	Ethiopia National Meteorology Agency
EPCC	Ethiopian Panel on Climatic Change
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICRAF	World Agroforestry Centre (International Council for Research in Agroforestry)
KII	Key Informant Interview
NAMAs	National Appropriate Mitigation Actions
NGOs	Non Governmental Organizations
PSNP	Productive Safety Net Programme
SLM	Sustainable Land Management
TLU	Tropical Livestock Unit
UNCCD	United Nations Convention to Combat Desertification
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development programme
UNFCC	United Nations Framework Convention on Climate Change
UNFCC	United Nations Framework Convention on Climate Change
USAID	United State Agency International Development

GLOSSARY

Belg	Small rainy season mostly from February to April
Bona	A season from October to May
Debo/jigi	Labor sharing mechanism in which household mobilize large number of individuals to work on his/ her farm land mostly without reciprocation.
Dega	Agro-climatic zone that lies between 2400 and 3300 meter above sea level.
Genna	Main rainy season like other Ethiopia highlands which extends from June to September
Kebele	It is the smallest administrative unit in Ethiopia.
Kolla	Agro-climatic zone that lies between 500 and 1500 meter above sea level.
Meher	Long rainy season based on summer rainfall
Mahiber	Spiritual organization established by the name of Glorified Saint.
Senbete	Spiritual organization of the Holy Sunday in Ethiopian Orthodox Church
Wenfel	Labor sharing mechanism among households on the basis of reciprocation with equivalent reciprocation with equivalent labour.
Woinadega	Agro-climatic zone that lies between 1500 and 2400 meter above sea level.
Woreda	Lower administrative unit in Ethiopia that is above the kebele and below zone.

CHAPTER I

INTRODUCTION

1.1 Background

Agriculture is the economic foundation of Ethiopia. Employing about 72.7 percent of the workforce and contributing nearly 36 percent of gross domestic product and 81 percent of foreign exchange earnings (NBE , 2018). Despite the marginal decline in its share in GDP in recent years, it is still the key sector in terms of its contribution to macroeconomic development of Ethiopia.

To boom the sector sustainably for enhancing the livelihood status of smallholder farmers, the sector needs suitable climatic condition. However, Ethiopia's climate is changing. Across the country, rainfall patterns are set to alter. In many areas droughts become more frequent, more intense, and last longer (Belay and Getaneh , 2016). In others, new patterns of rainfall will cause flooding and soil erosion. Climate change is emerging as one of the major threats to the nation development (Belay, 2016). Since, agriculture is highly vulnerable to climate change , food insecurity remains a concern among million's. Ensuring food security under a changing climate is one of the major challenges of our era.

A research conducted in Northern Ghana by employing the Ricardian regression models argued that precipitation and temperature impacted significantly on net revenue per hectare of maize and sorghum. Indeed, increasing precipitation (by 1 mm), while decreasing temperature (by 1 °C), would affect net revenue, but differently across seasons and among various crops (Zougmoré,R. et al 2016). This confirms the important link between climate and crop revenue and the need to take actions.

Climate change fundamentally and increasingly affects agriculture. Warming, drought and extreme weather are already altering yields and quality of crops produced around the world (Arman, G. et al ,2016). They also stand to impact water availability, nutritional value of foods, and food security and as such the livelihoods of natural resource dependent communities as a whole (FAO, 2016). The economic effects are already being felt by farmers and across global supply chains. Agricultural businesses identify climate change as a serious long-term risk in supply management (The Rainforest Alliance 2016 : 2).

Climate change will have far socioeconomic consequences for national economies and individuals. Climate change impacts on production are expected to translate into economic impacts at various scales. At the farm level, climate change will cause reduced income for households which will limit the capacity to acquire physical assets and meet the cost of child education and health (Belay and Getaneh , 2016). Therefore, developing or reinforcing adaptive mechanisms to deal with the negative effects of climate change should be considered as priority task for policymakers and institutions by promoting climate-smart agricultural (CSA) .

The promotion of CSA practices is one mainstream opportunity to mitigate climate change while sustaining the productivity of agricultural systems. In addition, CSA can help build adaptive capacity, so that: farmers, service providers to farmers and key institutions have the ability to respond effectively to longer-term climate change as well as being able to manage the risks associated with increased climate variability (FAO ,2016).

As a number of research depict, food security, poverty and climate change are closely linked and should not be considered separately (Nciizah and Wakindiki ,2015; FAO,2013;UNDP , 2011). In Africa alone, 650 million people are dependent on rain-fed agriculture in fragile environments that are vulnerable to water scarcity and environmental degradation. These areas are also susceptible to the negative impact of climate-related disasters such as droughts, floods and erratic weather patterns. This affect food security among the most vulnerable communities. According to FAO (2010), climate smart agriculture is taken as a solution to such a chaos. Meaning, Major productivity gains are possible given the large gaps between current yields and the yields that are possible with improved inputs and management while also promoting low GHG emission options. But it is not an easy task. Despite the potential benefits CSA could offer, it is confronted with many challenges.

The government of Ethiopia has given significant priority to the agricultural sector and has taken a number of efforts to increase productivity. The strong dependence of the country on agriculture, which is very sensitive to climate variability and change, is a major concern.

According to FAO (2016:4),

> Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO_2e in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In

> agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural land, which accounted for over 50 percent of forestry related emissions, followed by fuel wood consumption at 46 percent of forestry-related emissions.

A number of studies argued that, the agriculture status of Ethiopia is characterized by low agricultural production and productivity (FAO,2016 ; FDRE , 2011; Nigatu and parikh , 1999). Such low productivity is emanating from environmental factors such as climate change, soil erosion and land degradation as well as weak extension services (Ibid). Therefore, improving productivity while addressing the adverse effects of climate change on agriculture is a major concern in recent researches on Ethiopia agriculture (FAO 2016).

Practically, Various types of indigenous CSA practices have been implemented and adopted in Ethiopia. Such practices include the Derashe Traditional Conservation Agriculture, Konso Cultural Landscape, Hararghe Highland Traditional Soil and Water Conservation, Hararghe Cattle Fattening, Hararghe Small-Scale Traditional Irrigation, Ankober Manure Management and Traditional Agroforestry in Gedeo Zone, East Shewa Zone, East Wollega Zone and West Gojam Zone (FAO 2016; Zenabu , 2015).

Nevertheless, in order to strengthen and make the existing CSA practices be effective, identification of the identification of the bottlenecks to invest on CSA is required to scale up the practices. Also, knowing key factors that influence CSA practices adoption by rural farmers help to reinforce the adaptive and mitigation potentials of farmers.

1.2 Statement of the problem

Climate change and variability have been of great concern around the world in recent years. Especially in developing countries, adverse effects of climate change and variability remain to be a major threat to smallholder farmers and rural livelihoods (FAO , 2013). Ethiopia's low level of economic development with its heavy dependence on rain- fed agriculture, which is the sector most vulnerable to climate change make the country susceptible to the adverse effects of climate change (Belay ,2016).

Gerar Jarso woreda, in North Shewa Zone of Oromia regional state which is the focus of this particular study , is among the most vulnerable to climate variability and change. The central highlands have long been considered Ethiopia's most famine-prone areas (USAID ,2012). The woreda farming system is characterized by low productivity, low use of farm inputs, traditional farm practices, poor soil fertility, water logging and other related problems (Dereje and Haymanote ,2017).

To combat the adverse effects of climate change several measures have been suggested in attempts to reduce the vulnerability of smallholder farmers who are the worst affected by changes in climate. One such intervention is climate smart agriculture (CSA) (FAO ,2010), which is probably one of the most viable and sustainable option. It offers triple wins; Mitigation and adaptation measures to climate changes and sustainably increasing agricultural productivity and incomes. However, the adoption of climate smart agricultural practices is far below the expectation (Paulos ,2018). Besides, adoption of CSA practices study in Ethiopia were conducted at macro scale and the theme needs further research (FAO , 2016 ; Nciizah, and Wakindiki, 2015; Branca et al 2011). Thus, this thesis tried to understand the local scale adoption determinants and challenges at micro-scale study.

In countries like Ethiopia, where the economy is heavily relay on agriculture, development of the agricultural sector could be the most efficient poverty reduction measure. Yet, agricultural expansion for food production and economic development which comes at the expense of Soil , water , biodiversity and forest conflicts with the nation's green economy development goals , and often compromises production and development in the longer term. Ethiopia has initiated the Climate-Resilient Green Economy (CRGE) initiative to protect the country from the adverse effects of climate change and to build a green economy that will help to realise its ambition of reaching middle income status before 2025. "Improving crop and livestock production practices for higher food security and farmer income while reducing emissions," (FDRE 2011) is one of the four pillars of CRGE which mainly focus on agriculture. To fulfil the above target, CSA practices are needed. In the National Appropriate Mitigation Actions (NAMAs), the planned mitigation technologies and practices by agriculture sector is presented practicing composting 80000km^2 of cropland and agroforestry on 261840 km^2 (FDRE,2011). Therefore, assessing the determining factors nature of the practices and the status of the practices are a timely research themes.

Adoption studies in Ethiopia started in the mid 1970. Some of these studies were carried out in areas where integrated rural development projects had been undertaken following the introduction of integrated rural development pilot projects and minimum package programmes during the imperial regime in some parts of the country (Cohen, 1975).

Variables such as farm size , farm income , farming experience and soil type are frequently assessed as a determinant variables of adoption of agricultural technologies among Ethiopian rural farmers. (Negatu 1999, Kebede et al 1990 and Ashenafi ,2006). The technologies treated in the research were single ox, pesticides, fertilizers and improved seeds. (Ibid.)

Since, CSA is a new agricultural development scheme, it demands adoption studies to explore its determining factors . Nowadays, the need and implementation practices of CSA are growing among different development capacity building agencies. In most cases to implement eco- friendly agricultural practices, agro ecological assessments are done. Soil type, precipitation level and temperature status are the common parameters analysed to adopt innovative agricultural practices. (CASCAPE, 2016). However, without a critical assessment on the adoption potential of the target groups beyond agro ecological parameters , it is hard to attain sustainable agricultural productivity at the face of climate change . So, socio economic and institutional dimensions of the target groups must be analysed in CSA practices adoption. Therefore in this research, the farm household basic profile characteristics, biophysical characteristics, financial/management characteristics and social/institutional characteristics are analyzed to substantiate the adoption potentials of rural farmers in the study area. The result may provide what prior actions should be taken before implementation of CSA practices in rural farmers.

1.3 Objective of the Study

The general objective of the study is, to assess determinants and challenges of climate smart agricultural practices adoption in Gerar Jarso woreda of Oromia regional state.

The specific objectives are :

- to assess trends of climate variability and climate change and farmers' perception
- to examine farmers' view towards CSA.
- to examine the major determinant factors affecting farmers' to adopt climate smart agricultural practices .
- to assess challenges to invest and expand climate smart agricultural practices.

1.4 Scope and Limitation of the Study

The study was conducted in Gerar Jarso wereda of Oromia region. The result can't represent Ethiopia as a whole. Though, climate smart agricultural practices are more than a dozen, the study focused only three practices namely : composting , agroforestry and mulching practices. Besides , since agriculture encompasses different activities , the study focused only on crop farming agriculture. Owing to the constraints of time and financial resources , this study is limited to one –shot survey of cross sectional data collected from respondents. Since adoption is mainly dynamic process, in this research overtime trends are not addressed.

1.5 Significance of the Study

Climate change is emerging as one of the major threats for agricultural production and productivity. The high vulnerability nature of the sector demands adoption of climate smart agricultural practices to enhance sustainable agricultural productivity through simultaneous actions of adaptation and mitigation.

There are various determinants that positively or negatively contribute towards adoption of CSA practices. Identification of these determinants are crucial for policy makers, researchers and organizations involved in application of CSA practices in their development programs to enhance the livelihoods of rural households. Assessing the adoption level of rural farmers, could also be useful for designing policies to enhance their capacity to reduce greenhouse gas emissions and cope with climate change risks and impacts.

1.6 Organizations of the Thesis

This research thesis contains five chapters. The first chapter introduces the background, the statement of the problem, objectives, scope, significance and limitations of the study. The second chapter covers review of related literature that is related to the subject matter. The third chapter is about materials and methods, which consists of description of study area, sample design, sampling techniques, data collection and data analysis methods. Results and discussion parts of the study are found in chapter four. Chapter five concludes the major findings and suggests recommendations.

CHAPTER II

LITERATURE REVIEW

2.1 Climate Change and Agriculture

2.1.1 Climate change and variability in agriculture

Climate change is a change of climate which is attributed directly or indirectly to human activity. It alters the composition of the global and/or regional atmosphere and natural climate variability observed over comparable time periods (IPCC, 2015). Climatic variabilities are the types of changes (temperature, rainfall, occurrence of extremes); magnitude and rate of the climate change that causes the impacts on the area of public health, agriculture, food security, forest hydrology and water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services (FAO ,2017). Changes in physical and socio-economic system have been identified in many regions (UNFCCC, 2007). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature is likely to rise by 1.8 degrees to 4.0 degrees Celsius by 2100. The sea level may rise by 30 to 60 centimeters. Climate variability will increase almost everywhere. Northern latitudes will experience more rainfall; many subtropical regions will see less (IPCC, 2001).

Detecting these changes and associating them with climate change poses huge problems since these systems are usually subject to many stress factors other than climate change too. Vulnerability is the degree to which a system (such as a social-ecological system) is likely to be wounded or experience harm or stress in the natural or social environment (FAO ,2013). Vulnerability results from a combination of processes that shape the degrees of exposure to a hazard, sensitivity to its stress and impacts, and resilience in the face of those effects. It is also considered a characteristic of all people, ecosystems, and regions confronting environmental or socioeconomic stresses and, although the level of vulnerability varies widely, it is generally higher among poorer people (Belay , 2016).

Baseline climate that was developed using historical data of temperature and precipitation from 1971-2000 for selected stations in Ethiopia showed the year-to-year variation of rainfall for the period between 1951 to 2005 over the country expressed in terms of normalized rainfall anomaly averaged for 42 stations (NMA, 2007). The country during those periods

(1951 to 2005) has experienced both dry and wet years over the last 54 years. These changes in the physical environment are expected to have an adverse effect on agricultural production, including staple crops such as wheat and maize. Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern and Southwestern Ethiopia (IPCC, 2007).

The rainfall is highly variable both in amount and distribution across regions and seasons. The seasonal and annual rainfall variations are results of the macro-scale pressure systems and monsoon flows which are related to the changes in the pressure systems. The spatial variation of the rainfall is influenced by the changes in the intensity, position, and direction of movement of these rain-producing systems over the country (Temesgen, 2000).

Moreover, the spatial distribution of rainfall in Ethiopia is significantly influenced by topography which also has many unexpected changes in the Rift Valley. Being a closed basin, relatively small interventions in land and water resources can have far-reaching consequences for ecosystems goods and services, and potentially undermine the sustainable use of the area.

The National Metrological Agency (2001) revealed that in Ethiopia climate variability and change in the country is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences. For the IPCC mid-range emission scenario, the mean annual temperature will increase in the range of 0.9 -1.1 °C by 2030, in the range of 1.7 - 2.1 °C by 2050 and in the range of 2.7-3.4 °C by 2080 over Ethiopia compared to the 1961-1990 normal(USAID ,2012). A small increase in annual precipitation is expected over the country. Historical climate analysis for Ethiopia indicates that mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade (Ibid). The increase in temperature in Ethiopia has been most rapid in June, August, and September at a rate of 0.32°C per decade. Rainfall is historically highly variable and there is no clear trend in the amount of rainfall over time. Mean annual temperature is projected to increase by 1.1 to 3.1°C in the 2060s, and 1.5 to 5.1°C in the 2090s (McSweeney et al, 2008). Under a single emissions scenario, the projected changes from different models span a range of up to 2.1°C (Ibid).

The significant range between these climatic condition highlights the uncertainty in future projections for climate change in Ethiopia. Clearly Ethiopia is highly vulnerable to current variability and there are also indications that climate change will increase rainfall variability which will likely increase losses from rain-fed agriculture (Belay and Getaneh ,2016; Arman ,G. et al, 2016; Temesgen and Daniel, 2014). The ecosystems of the country as well as its community are highly exposed to climatic variability. Ethiopia is vulnerable to climatic variability owing to its low adaptive capacity accountable to low level of socioeconomic development, high population growth, inadequate infrastructure, lack of institutional capacity and high dependence on climate sensitive natural resource-based activities (Belay , 2016).

Today climate change and variability are concerns of human being at global level. The recurrent droughts and floods threaten seriously the livelihood of billions of people who mainly their livelihood depend on agriculture. The global economy is adversely being influenced very frequently due to extreme events such as droughts and floods, cold and heat waves, forest fires, landslips etc. The loss of forest cover, which normally intercepts rainfall and allows it to be absorbed by the soil, causes precipitation to reach across the land eroding top soil and causes floods and droughts. Paradoxically, lack of trees also exacerbates drought in dry years by making the soil dry more quickly. A research conducted by World Bank in Morocco revealed that, due to reduced rainfall and higher temperatures, aridity increases and agricultural yields declines (world Bank , 2009).

Climate change has already significantly impacted agriculture and is expected to further impact directly and indirectly food production. Increase of mean temperature; changes in rain patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'; sea level rise and salinization; perturbations in ecosystems, all will have profound impacts on agriculture, forestry and fisheries (FAO , 2013). Rainfed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, crop yields are expected to continue to increase in spite of climate change. However, availability of water for irrigation is uncertain (FAO , 2013).

Broadly speaking, with everything else being equal, climate change may lead to an increase in both crop and livestock productivity in mid- to high latitudes (IPCC, 2007) and a decrease in tropical and subtropical areas. Among the most affected areas are economically vulnerable countries already food insecure and some important food exporting countries.

As it is indicated in Table 1, Crop production is increasingly vulnerable to risks associated with new and evolving climatic changes. These are variations in environmental conditions that pose significant challenges to farmers, over and beyond those that are experienced 'normally.' The planet is facing more extreme weather events, such as heavy precipitation, higher coastal waters, geographic shifts in storm and drought patterns, and warmer temperatures (IPCC, 2012).

Table 1. Examples of projected climate change impacts on crop production

Event	Potential impact
Cold periods becoming warmer and shorter; over most land areas, days and nights becoming hotter (*virtually certain)*	Increased yields in colder environments; decreased yields in warmer environments; increased outbreaks of new insect pests and pathogens; potential impacts on crop production
Heavy precipitation events increasing in frequency over most areas (*very likely*)	Damage to crops; soil erosion; inability to cultivate land owing to waterlogging of soils
Drought-affected area increases (*likely*)	Land degradation and soil erosion; lower yields from crop damage and failure; loss of arable land
Intense tropical cyclone activity increases (*likely*)	Damage to crops
Extremely high sea levels increase in incidence (excludes tsunamis) (*likely*)	salinization of irrigation water, estuaries and freshwater systems; loss of arable land

(Source : Adapted from FAO, 2013)

Case studies (Paulos ,2018;Belay, 2016) indicate that Ethiopian agriculture is highly vulnerable (with large spatial and temporal variation) to the impacts of climate change because of high exposure and sensitivity of the sector to climate variability and change. It is also because low adaptive capacity of smallholder farmers. The vulnerability of the agriculture sectors to impacts of climate change is exacerbated by non-climatic drivers such as inappropriate land use and land degradation, population pressure, subsistence farming, low technological innovation and application and poverty (Nathnael , 2017).

While agriculture is the sector most vulnerable to climate change, it is also a major cause of climate change, directly accounting for about 14 percent of global greenhouse gas (GHG) emissions, and indirectly much more as agriculture is also the main driver of deforestation and land-use change responsible for Another 17 percent of global emissions (FAO , 2013). Even if emissions in all other sectors were eliminated by 2050, growth in agricultural emissions in a business-as-usual world with a near doubling in food production would Perpetuate climate change (Ibid).

According to FAO (2016), Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO2 e in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural percent of forestry related emissions, followed by fuel wood consumption at 46 percent of forestry-related emissions. The major sources of GHG emissions within the agriculture sector of Ethiopia. The largest proportion of emissions results from enteric fermentation, followed by manure left on pasture, both of which are related to livestock production (Figure 1).

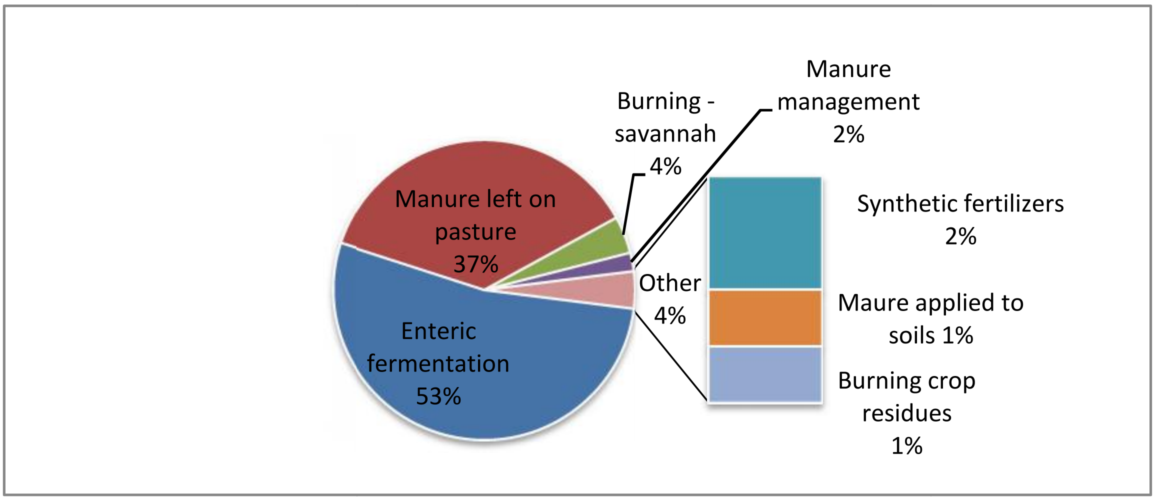


Figure 1. GHG emission source in Ethiopia(Adapted from FAO ,2016)

The overall efficiency of the agricultural sector– its resilience, adaptive capacity and its land, which accounted for over 50 potential for contributing to the mitigation of the effects of climate change and variations– can be enhanced by improving these constituent components. Indeed, by improving the efficiency of agricultural production, emissions can be reduced and sequestration capacity enhanced (Pretty et al., 2011).

Mitigation and adaptation are the two fundamental instruments of the international climate convention to minimize negative impacts of climate change on humans and ecosystems. The less effective global mitigation is in reducing anthropogenic greenhouse gas (GHG) emissions and increasing GHG sinks, and the more adaptation is needed to avoid such negative impacts. Adaptation deals with enhancing the adaptive capacity and/or reducing vulnerability to climate change impacts while also taking advantage of the positive opportunities resulting from climate change. Despite both aiming to reduce the negative human and ecosystem impacts of climate change, the two measures are different in their specific objectives, scope, time dimension, and level of collaboration required (Lalisa et al 2014).

Ethiopia, relative to many African countries, richly endowed with water, the spatial and temporal distribution of water is highly uneven, making certain places and times of the year very dry and water scarce (Kbrom and Mehari , 2016). The rivers of Ethiopia exhibit typical characteristics of tropical rainfall-dependent flow regimes. Hence, the spatial and temporal distribution of rainfall governs amount and intra-and inter annual variability of water availability. This is due to mainly effected from the changing climate that is happening now around the globe. There by, the blessings of water have primarily positive implication to the agriculture sector among other economic reward to the country. If the changing climate causes negative connotation to the water sector of the country, it will definitely hamper to the country's GDP in one way or another (EPCC , 2015). Hence, adaptation and mitigation options or strategies need to be devised, implemented and/or scaled up the existing ones to offset the current and predicted impacts of climate change to the agriculture and water sectors of the country.

2.1.2 Climat Change Mitigation and Agriculture

There is much concern that the increasing concentration of greenhouse gases in general, and carbon dioxide in particular contributes to global warming by trapping long-wave radiation reflected from the earth's surface (FAO,2013). Over the past 150 years, the amount of carbon in the atmosphere has increased by 30% (Ibid). Most scientists believe there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global temperatures (Stavins and Richards, 2005).

Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation, together with adaptation to climate change, contributes to the objective expressed in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC):

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (IPCC ,2015:4).

Ethiopia's per capita emission of less than 2 ton CO_2 Dioxide equivalent) is low compared to more than 10 ton in the EU and more than 20 ton in the US and Australia. The country's total emissions of around 150 Mt CO_2 e represent less than 0.3% of global emissions (FDRE , 2011). The agriculture sector is one of the major contributors of GHG (Green House Gas) emissions in Ethiopia through the crop, livestock and natural resources carbon footprints (like as a result of soil degradation and land use change from forest land to agricultural land). Ethiopia intends to limit its net GHG emissions in 2030 to 145 Mt CO_2e or lower. This would constitute a 255 MtCO_2e or 64% reduction from the Business As Usual (BAU) emissions in 2030, which would otherwise become 400 Mt CO_2 e with BAU in the same year (Belay , 2016 ; Nathnael , 2017).

GHG emission has impacted the agriculture sector in a way that rainfall variability and associated yield reductions are estimated to cost Ethiopia around 38% of its potential growth rate and increase poverty by 25% (World Bank ,2006). Since the country's main-stay and/or economy are based on agriculture, climate change could negatively affect agriculture. Thus, it will ultimately reduce GDP by 3-10% by 2025 (Nathnael , 2017). Results show that warmer temperature is beneficial to livestock agriculture, while it is harmful to the Ethiopian economy from the crop agriculture point of view (Ibid). Moreover, increasing/decreasing rainfall associated with climate change is damaging to both (crop and livestock) agricultural activities.

According to different studies , variety of mitigation strategies to immune level of emissions particularly from the agriculture sector (i.e., from crop, mainly livestock and natural resources) are drawn. Some of the identified mitigation strategies are: reducing expansion of cultivated land through agricultural intensification (increasing productivity by reducing Green House Gas (GHG) emission: conservation agriculture, compost, wise use of inorganic fertilizers, proper crop management); improving animal productivity through breeding; feedlots practice by smallholder farmers; improving feed and feeding management; diversification toward lower emitting animal species (small ruminants); mechanization; manure management; afforestation/reforestation; agroforestry; soil and water conservation and land rehabilitation; and reducing rate of desertification. (Belay , 2016 ; Nathnael , 2017; Temesgen et al , 2009).

2.1.3 Climate Change Adaptation and Agriculture

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

By 2050, it is predicted that the global population will be over 9 billion people, increasing the demand for food and other agricultural products (FAO, 2013). At the same time, the world faces challenges such as land and water scarcity, increased urbanization, and climate change and volatility. Agricultural production remains the main source of income for most rural communities (about 86 percent of rural people - 2.5 billion), who depend on agriculture for their livelihood (World Bank, 2008). Improving adaptation of the agricultural sector to the adverse effects of climate change will be imperative for protecting and improving the livelihoods of the poor and ensuring food security. In practical terms, climate change adaptation requires more than simply maintaining the current levels of performance of the agricultural sector; it requires developing a set of robust and yet flexible responses that will improve the sector’s performance even under the changing conditions brought about by climate change engenders (FAO , 2013).

According to FAO (2013), Main climate change exposure for densely populated highlands and poor areas like Himalayas, Andes, Central American highlands, Rift Valley, Ethiopian plateau, Southern Africa etc. are rainfall variability, droughts, floods. They are vulnerable because , rainfed agriculture, marginal lands and poor soil moisture capacity are the very nature of the agricultural potential. The high prevalence of poverty, limited options, knowledge, social safety nets and resources drive to have low adaptive capacity. So, watershed management and on farm water storage for water conservation; integrated water resources management in river basins and investment in social infrastructures are advised to be a typical response option.

Adapting to climate change will entail adjustments and changes at every level from community to national and international. Communities must build their resilience, including adopting appropriate technologies while making the most of traditional knowledge, and diversifying their livelihoods to cope with current and future climate stress. Local coping strategies and traditional knowledge need to be used in integrated with government and local interventions. To enable effective adaptation measures, governments as well as non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making (Belay , 2016).

Decisions on the type of adaptation are often made by individuals, groups within society, and organizations and governments on behalf of society. Some adaptation measures may be taken at individual level. Others like rainwater harvesting and investments, building dams, releasing new cultivars that are more drought resistance require collective actions. These time societies have inherent capacities to adapt to climate change and have developed different adaptation and mitigation strategies to combat climate change. They have developed knowledge, skills, technology, institutional arrangements and strategies that are important foundations for adapting to long-term climate change. Based on the type of economic activities and social networks societies can access local coping strategies against shocks. These highly differ among households and communities. Communities have always adapted to climate variations by making preparations based on their resources and knowledge accumulated through experience of past weather pattern. The adaptive measures that households use when faced with climate change could also differ in terms of their ease of implementation, equity effects, lag between implementation and effect, their cost of implications, compatibility with other programs, and agencies implementing measures (Admassie, 2008).

Climate adaptation measures will need to address systemic weaknesses and vulnerabilities that have historically impoverished those communities. Climate change will challenge the implementation of current and future development plans: adjustments and changes will be required at every level: community, national and international. A better understanding of the impacts, costs, changes and communities perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policy makers and sector institutions aimed at promoting successful adaptation strategies for the country development programme. Ethiopia will need to both mitigate the impacts of climate change, where possible, and adapt to the situation where it cannot (Yesuf et al, 2008).

As impact will differ regionally, based on the bio-physical and socioeconomic situations within Ethiopia, the management of impacts will need to be defined for each region based on the analysis of current information and practices, the scope for variability within these systems and the possibility of alternative farming and livelihoods. Given the challenges outlined above, delivering an integrated response will require enhanced capacity for coordinating and leading ‘joined-up’ actions. New technologies, as well as current technologies used in new ways can support this response, but only if the appropriate enabling institutional and policy environment is in place to encourage joint working and embrace adaptive learning to take account of ongoing uncertainties or new opportunities (Tadege, 2007).

Studies in Ethiopia indicate that, the dominant adaptation methods practised by Ethiopian crop producing farmers include: use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation adoption of mixed crop and livestock farming systems and changing planting dates (Temesgen et al 2009; Temesgen, 2014; Nathnael, 2017).

2.2 Conceptualizing Climate Smart Agricultural Practices

2.2.1 Concept definition

Climate Smart Agriculture (CSA) as a concept was developed in 2010 by the Food and Agriculture Organisation (FAO). It is an approach to reorienting agricultural and cattle production to the new realities of climate change. It creates the technical, policy and investment conditions for achieving sustainable agricultural development and food security as climate change unfolds. It is composed of three main pillars:

- sustainably increasing agricultural productivity and incomes ;
- adapting and building resilience to climate change; and
- reducing and/or removing GHG emissions where possible. (FAO, 2013).

Climate smart agriculture is not a defined set of practices or an entirely new type of agriculture. Rather it is an approach that combines different methods under a climate change umbrella. It assesses the risks and needs of a specific farm or farming community through a climate impact lens, then addresses them using practices chosen for that particular situation (2016). It gives farmers tools and a pathway to make their operations and livelihoods more productive and resilient in the face of climate change, while also helping reduce their climate impacts. It integrates the three dimensions of sustainable development by jointly addressing food security and climate change challenges (Nciizah and Isaiah ,2015). The focus is generally on improving the currently existing techniques, such as the usage of fertilisers and pesticides, but with better-applied efficiency and improved seeds (for instance, drought resistant seeds) (FAO 2010).

As research and policy links between climate change and agriculture have advanced, climate-smart agriculture has emerged as a framework to capture the concept that agricultural systems can be developed and implemented to simultaneously improve food security and rural livelihoods, facilitate climate change adaptation and provide mitigation benefits. Since it emerged in 2010, the development of this idea and use of the term itself, has been led by international institutions, particularly the United Nations Food and Agriculture Organization (FAO) and the World Bank. The Consultative Group on International Agricultural Research (CGIAR) has provided leadership to the international research community as the idea has matured. (Sara J Scherr et al 2012)

According to FAO, CSA is a more comprehensive development concept compared to agro-ecology. At its launch (2010), it was however heavily criticised, especially by civil society and farmers organisations, for lacking specific indicators, thereby also for risking to focus too narrowly on mitigation instead of adaptation that is more urgent in poor developing countries. The CSA community responded to this criticism by broadening its scope. CSA now links environmental, social and economic pillars of sustainability, and covers farm level practices, landscape level approaches, and institutional/policy level frameworks, as shown in Figure 2. The CSA concept is relatively flexible and is still "work in progress", since the approach remains context-specific and needs to be always tailored to local and regional realities. The CSA label is extensively used by internationally renowned research centres and organisations such as the World Bank, FAO, the Consultative Group for International Agricultural Research (CGIAR) and its Climate Change, Agriculture and Food Security (CCAFS) programme, the International Center for Tropical Agriculture (CIAT), the International Food Policy Research Institute (IFPRI), the UK Department for International Development (DfID), the Rockefeller Foundation, as well as African policymakers. (Hanne Knaepen et al 2015 : 4)

	Food Security (Sustainable productivity improvement)	Adaptation (Building resilience)	Mitigation (reducing GHG emissions and enhancing GHG removal)
Farm issues	- Sustainable intensification - Integrated farming - Improved nutrient and water management	- Conservation agriculture - Adjust crop calendars - Use different crop cultivars and animal species and strains - Integrated pest, disease and weed management	- Precision agriculture - Improve soil-carbon storage/Develop carbon sequestration options (conservation tillage, cover cropping, crop rotation)
Landscapes and regional issues	- Landscape approach - Restoration of degraded farm lands, wetlands and forests	- Ecosystem-based agriculture (to improve ecosystem services) - Agro-forestry (enhance the role of forests)	- Agro-ecology
Institutional and policy issues	- Strengthening science-policy linkages - CSA mainstreaming in agricultural development policy frameworks - Trade-offs between diversification vs. specialization - Gender, youth involvement & reduction inequalities	- Enhanced weather information systems and advisory services - Empower women and the poor - Pro-poor financing, insurance mechanisms and safety nets	- Incentives for pro-poor mitigation

Figure 2 . The three pillars of CSA (adapted from Knaepen, et al . 2015)

Climate Smart Agriculture seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage on farmland. Climate-smart agriculture includes proven practical techniques — such as mulching, intercropping, conservation agriculture, Crop rotation, integrated crop-livestock management, agro forestry, improved grazing, and improved water management — but also innovative practices such as better weather forecasting, early warning systems and risk insurance. It is about getting existing technologies off the shelf and into the hands of farmers and developing new technology such as drought and flood tolerant crops to meet the demands of the changing climate. It is also about creating and enabling policy environment for adaptation. Climate-smart agriculture fully incorporates attention to climate risk management. In many regions, agriculture is an extremely risky business, and climate change will exacerbate this.

2.2.2 What is new with Climate-smart agriculture?

In the last decades, farming systems approaches have brought to light insights related to institutions and policy, participation, multi-stakeholders partnerships and people's rights, environment and agro-ecosystems as well as multidisciplinary and multi sectoral mechanisms and their interdependence. Some of the "labels" currently used relate to practices at farm level (for instance, sustainable intensification), whereas some others relate to comprehensive, holistic approaches (for example, CSA). Some of them promote a more "nature-driven" agriculture (like eco-intensive agriculture or agro-ecology), while some others support a more "technology driven" agriculture (like precision agriculture) (Knaepen, et al . 2015).

These concepts have evolved over time in line with new emerging issues and more scientific knowledge becoming available. In principle, all such approaches are complementary**,** and they can be gathered under the "Sustainable Agriculture" (SA) umbrella, including green agriculture , CSA, agro-ecology, ecosystem-based adaptation (EbA) for food security, the landscape approach, eco-intensive agriculture and sustainable intensification, amongst others. Sustainable Agriculture, like "sustainable development", has encompassing benefits from social, environmental and economic angles. It describes farming systems that are 'capable of maintaining their productivity and usefulness to society indefinitely. Such systems must be resource conserving, socially supportive, commercially competitive, and environmentally sound' (Knaepen, et al . 2015).

Though , CSA concept was developed by the Food and Agriculture Organisation (FAO) in 2010, it is not considered as a new agricultural system, nor is it a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change (FAO , 2013b).

CSA shares with sustainable development and green economy objectives and guiding principles. The 1992 Earth Summit and Rio Declaration recognized the value of the environment in development activities and integrate economic, environmental and social dimensions. The Rio convention also include the United Nations Framework Convention on Climate Change (UNFCCC). Also practically speaking , a green economy is one whose growth in income and employment is driven by investments that simultaneously: reduce carbon emissions and pollution, enhance energy and resource-use efficiency; and prevent the loss of biodiversity and ecosystem services (FAO , 2013a).

The green economy and CSA share the common goal of integrating the three dimensions of sustainable development. Both make sustainable development tangible by focusing on issues that can and must be addressed right now in local communities but that have global, long-term consequences. CSA brings together global and local concerns, climate change to be addressed globally, climate change to get adapted to locally; and first of all, food security, which has to be addressed both locally and globally. To do so it brings together practices, policies and institutions, which are not necessarily new. What is new is the harmonization and synchronization needed of practices and policies in order to address multiple challenges, faced by agriculture and food systems, now and for the future. What is also new is the objective of avoiding contradictory and conflicting policies by internally managing trade-offs and synergies in the pursuit of multiple objectives (FAO , 2013b).

2.3 Climate Smart Agricultural practices in Ethiopia

As fundamental to livelihoods and food security improvement programme , both traditional and innovative agricultural practices are conducted in Ethiopia. Currently, agricultural development activities carried out in the country are supported by a number of policies, strategies and institutions. Of the numerous agricultural development activities conducted, CSA practices mentioned in elaborative manner are considered important in addressing issues related to climate change and are contributing to climate change adaptation and mitigation (Table 2) . Such agricultural practices in Ethiopia include integrated watershed management, integrated soil fertility management, sustainable land management, conservation agriculture, agroforestry, crop residue management, composting, promotion of improved livestock feed and rangeland management (FAO, 2016).

Ethiopia is one of the countries heavily affected by land degradation, and addressing this problem is a major priority task for the country. In Ethiopia integrated watershed management is conducted through various projects and programmes, which include the Sustainable Land Management Programmes (SLMP1 and SLMP2), Managing Environmental Resources to Enable Transitions to more Sustainable Livelihoods (MERET) project, Productive Safety Nets Programme – Public Works (PSNP-PW) and numerous NGOs. CSA in SLMP2 refers to proven practical techniques — such as mulching, intercropping, conservation agriculture, no-till, crop rotation, cover cropping, integrated crop-livestock management, agroforestry, improved grazing and improved water management — and innovative practices such as use of drought-resistant food crops. In an effort to implement this programme in many parts of the country, reports indicate that to date about 1 708 100 hectares of land were treated under area closures; and appropriate physical and biological soil conservation methods were applied to 2 076 000 hectares of land (Ibid).

Studies indicate that land and crop production and productivity have increased due to an increase in land available for cultivation, increased availability of water for irrigation, improvement in the fertility status of the soil as well as improved agronomic practices (Branca et al 2011). It is reported that soil organic matter content sequestration can be achieved by implementing sustainable land management practices that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure and enhance activity and species diversity of soil fauna. Some 12,500 households who adopted conservation agriculture, resulting in a 60% increase in crop yields (FAO , 2016). Also yields of crops from composted plots were 3 - 5 times higher than those treated only with chemicals. (Branca et al 2011; FAO , 2016; Nciizah, and Wakindiki, 2015).

Table 2. Some common CSA practices in Ethiopia

CSA practice	Components	Why it is climate smart?
Conservation agriculture	• Reduced tillage • Crop residue management-mulching, intercropping • Crop rotation/intercropping withcereals and legumes	• Carbon sequestration • Reduce existing emissions • Resilience to dry and hot spells
Integrated soil fertility management	• Compost and manure management, including green manuring • Efficient fertilizer application techniques (time, method, amount)	• Reduced emission of nitrous oxide and CH_4 • Improved soil productivity
Small- scale irrigation	• Year-round cropping • Efficient water utilization	• Creating carbon sink • Improved yields • Improved food security
Agroforestry	• Tree-based conservation agriculture • Practised both traditionally and as improved practice • Farmer-managed natural regeneration	• Trees store large quantities of CO • Can support resilience and improved productivity of agriculture
Crop diversification	• Popularization of new crops and crop varieties • Pest resistance, high yielding, tolerant to drought, short season	• Ensuring food security • Resilience to weather variability • Alternative livelihoods and improved incomes
Improved livestock feed and feeding practices	• Reduced open grazing/zero grazing • Forage development and rangeland management • Feed improvement • Livestock breed improvement and diversification	• Improved livestock productivity • GHG reduction • CH_4 reduction
Other	• *In situ* water	• Resilience of agriculture

	conservation/harvesting • Early-warning systems and improved weather information • Support to alternative energy fuel efficient stoves, biofuels • Crop and livestock insurance • Livelihoods diversification (apiculture, aquaculture) • Post-harvest technologies (agro processing, storage)	• Improved incomes • Reduced emissions • Reduced deforestation • Reduced climate risk

(Adapted from FAO , 2016)

2.4 Opportunities and Challenges to Implement CSA Practices in Ethiopia

In spite of the potential benefits of the system especially to smallholder farmers who bear the brunt of the effects of climate, there is much skepticism about the capacity of CSA to mitigate the effects of climate by fostering resilience l*et al*one feed communities (Nciizah, and Wakindiki, 2015) . Most of the household farmers in developing countries including Ethiopia are resource poor and they usually own degraded land (FAO ,2016). Also, a significant size of the farm lands are marginal with low yields. However, CSA would be the most appropriate system for such farmers since it uses locally available resources and does not rely on the use of external inputs (Magdoff, 2007).

As it is stated in Table 3, the current policies, strategies and laws related to climate change and CSA in Ethiopia are adequate. However, they are not adequately incorporated into extension guidelines and manuals (and the extension system as a whole) in a way that the great majority of the rural farming population could understand and participate in their implementation. For this reason adoption of practices such as conservation agriculture remains relatively low. The promotion of integrated watershed management to improve agricultural productivity, with major emphasis on avoiding open and uncontrolled grazing, sufficient resource endowment in the form of projects and programmes like AGP, SLM, PSNP and others and the availability of adequate numbers of extension and development agents at grassroots level provide a good opportunity for large-scale implementation and promotion of climate-smart practices. Lack of skilled human resources on climate change adaptation and mitigation at all levels, weak coordination mechanisms at federal and regional levels, lack of mechanisms to bring together and coordinate stakeholders involved in different forms of CSA technology promotion, the dominant nature of conventional agricultural practices like frequent ploughing and removal and burning of crop residues and the open grazing characterization of livestock husbandry are key challenges to implement CSA in Ethiopia (FAO, 2016). So, analysing the untapped opportunities and key challenges to upscale CSA is demanding for policy makers and practitioners to move forward.

CSA requires changes in farming households' attitude, strategies and planning, as well as changes in the usual timing of agricultural practices. All such expected changes Without appropriate institutional structures, supporting national policies and strategies may seem overwhelming to the adverse impact of climate change by smallholder farmers (FAO ,2013). Farmers need policies that remove obstacles to implementing climate-smart agriculture, and create synergies with alternative technologies and practices. Policies and strategies should recognize and support proven technologies for carbon sequestration, like mulching, intercropping and agroforestry. Considerable policy support and capacity enhancement is needed for climate risk management including insurance and safety nets, as well as improved access to weather information adapted to farmers' needs (Ibid). Ways and opportunities need to be found that strengthen synergies in the implementation of climate-smart agriculture and food security programs and initiatives.

At present, there is willingness and commitment from the Ethiopian government to reduce poverty and ensure food security while addressing climate change. The government has developed policies and strategies that are pertinent to ensure food security as well as address climate change. The government has put in place a number of policies, strategies and institutions that are designed to support climate change adaptation and mitigation and sustainable development as a whole. Moreover, Ethiopia has signed and/or ratified many of the international conventions and protocols related to climate change and land degradation including the United Nations Framework Convention on Climate Change (1994), the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD) (FAO , 2016; Belay, 2016).

Policies, laws and strategies relevant to climate change in Ethiopia include the Climate Resilient Green Economy Strategy (2011), National Adaptation Program of Action (NAPA), Ethiopian Programme of Adaptation to Climate Change (EPACC) of 2011, Nationally

Appropriate Mitigation Actions (NAMA) of 2010, Rural Development Policy and Strategies (2003), Growth and Transformation Plan (GTP), CAADP Compact and the National Environmental Policy of Ethiopia (1997).

The Climate Resilient Green Economy Strategy known as CRGE was developed in 2011 and launched at the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change in Durban in 2011. The strategy takes an economy-wide approach to greenhouse gas reduction. According to the strategy, Ethiopia aims to achieve carbon-neutral middle-income status before 2025. The strategy is based on four pillars, of which the first two pillars are mainly related to CSA. These are: "Improving crop and livestock production practices for greater food security and better income for farmers while reducing emissions" and "Protecting and re-establishing forests for their economic and ecological value, including carbon stocks " (FDRE , 2011: 22-24).

Table 3. Summary of key policies, laws and strategies relevant to CSA practices adoption in Ethiopia.

policy, law and strategy	Year	Intention or goal
Articles 43 and 44 of the Ethiopian constitution	1995	Government and citizens shall have a duty to protect the environment. The design and implementation of programs and projects shall not damage or destroy the environment.
Environmental Policy of Ethiopia	1997	Promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs'
Environmental Impact Assessment	2002	Ensure that the environmental implications are taken into account before any major development projects are made
National Adaptation Program of Action (NAPA)	2007	The NAPA represented the first step in coordinating adaptation activities across government sectors
The Comprehensive Africa Agriculture Development Program (CAADP) Compact	2009	One of the pillars of CAADP is extending the area under sustainable land management and reliable water control systems. CAADP has been endorsed by the African Heads of State and Government as a framework for restoration of agriculture growth, food security and rural development in

		Africa.
Growth and Transformation Plan (GTP I and II)	2010-2015/2016-2020	The GTP recognizes that the environment is a vital pillar of sustainable development. The GTP addresses climate change as a crosscutting issue under the strategic priority of environment and climate change.
Agriculture Sector Programme of Plan on Adaptation to Climate Change/APACC	2011	The Agriculture Sector Climate Change Adaptation Plan.
Ethiopian Programme of Adaptation to Climate Change (EPACC)	2011	More programmatic approach to adaptation planning
Climate Resilient Green Economy Strategy	2011	Carbon-neutral middle-income status before 2025

(Adapted from: FDRE ,1995; FDRE , 2011; FAO ,2016)

2.5 Climate Smart Agriculture Practices

Environmental stresses have always had an impact on crop production, and farmers have always looked for ways to manage these stresses. Climatic conditions that influence crop systems include: rain quantity and distribution, and consequently water availability; extreme events, such as floods and droughts; higher temperatures; and shifting seasons (FAO ,2013). At the field level, there are a wide range of agricultural practices and approaches that are currently available that can contribute to increased production while still focusing on environmental sustainability. Considering the ecological, social, policy and economic dimensions of a specific location, CSA practices can contribute to climate-smart crop production i.e. approaches to adapt to, and contribute to, the mitigation of climate change (FAO ,2016).

Some of CSA approaches and practices that contribute to climate change adaptation are: ecosystem-based approaches; conservation agriculture; integrated nutrient and soil management; mulch cropping; cover cropping; alterations in cropping patterns and rotations; crop diversification; using high quality seeds and planting materials of adapted varieties; integrated pest management; integrated weed management; grasslands management; water and irrigation management; landscape-level pollination management; organic agriculture; and land fragmentation (riparian areas, forest land within the agricultural landscape)(FAO,2013b). There are also many different approaches and practices for sustainable crop production that can contribute to climate change mitigation. Some of the widely practiced are : conservation agriculture; soil compaction management; improved farming systems with several crop rotations; crop diversification; promotion of legumes in crop rotations; growing cover crops; mulch cropping; restoration of cultivated peaty soils and degraded lands; soil management practices that reduce fertilizer use (e.g. urea deep placement); integrated nutrient management; growing nutrient-use efficient crop varieties; integrated crop and livestock systems; dedicated energy crops to replace fossil fuel use; emission control and reduction (combustion engines, animal waste); improved rice cultivation techniques; water management/conservation, irrigation, water table management; and agroforestry (FAO , 2016).

From a number of CSA practices three of them namely ; composting, mulching and agroforestry are selected in this research. In spite of the specificity of the research objective, the practices demand only local resources for adoption.

2.5.1 Composting

Composting as it is indicated in Figure 3, is a natural biological process carried out by a vast number and variety of decomposer organisms. Naturally occurring microorganisms, such as bacteria and fungi, account for most of the decomposition. Larger organisms, including insects and earthworms, also break down the materials, especially in the later stages of the process. From start to end, the composting materials change from a diverse mixture of individual ingredients, such as leaves, stems, and fruit, to a uniform soil-like material called compost (sometimes referred to as humus). (Rynk and Colt , 1997; de Bertoldi *et al.*, 1983). The metabolic activity and exothermic processes during the composting increases the temperature in the composting mass which creates a strong selective pressure in favour of thermophilic organisms. Various maturity indicators for composts have been suggested .Though there is no single parameter that completely defines maturity, the carbon nitrogen ratio and reduced rate of CO evolution from mature compost can be used as reliable indicators. Composting results in a reduction of the volume of organic material, destruction of weed seeds and sanitation through reduction of harmful pathogens. However, the process can also result in loss of N through ammonia volatilization (Goyal *et al.*, 2005). Amendment of soil with compost improves the biophysical and chemical properties of soils. Increases in soil organic matter (SOM), enhanced soil fauna and increased microbial biomass have been documented as a result of compost addition (Workneh, 2015 ; Mengistu and Bauer, 2011).

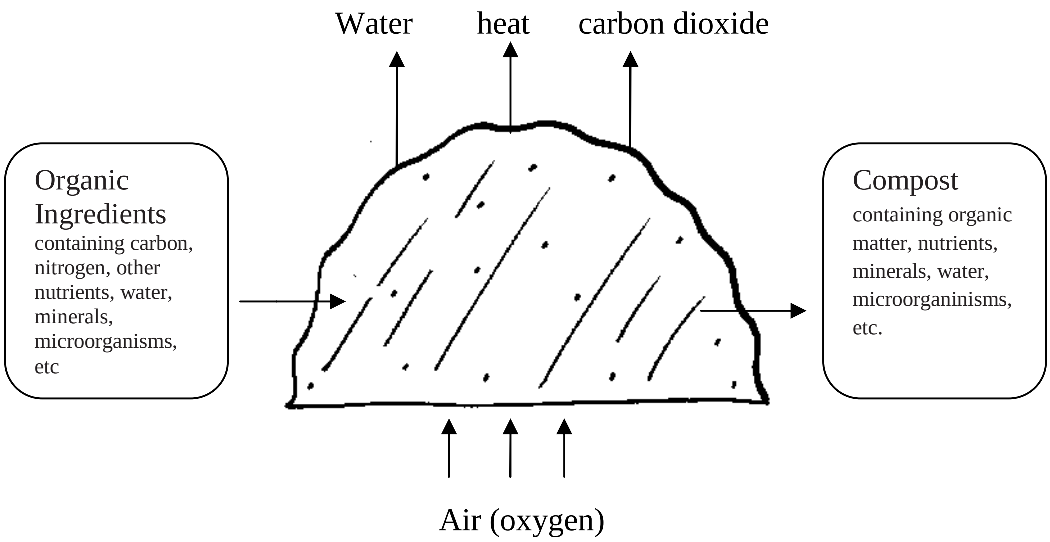


Figure 3. Basics of the composting process (Adapted from Rynk and Colt , 1997).

2.5.1.1 Composting as CSA practice

Compost additions to soil have the potential to improve soil physical conditions through increasing resistance to erosion, improving soil workability and water infiltration and water holding properties; improve soil fertility; increase soil biodiversity and sequester carbon in the soil (Huttle and Fussy , 2001). Significant number of studies showed a positive effect of compost on yield (Wassie , 2016;Workneh, 2015 ; Eric G.,2012; Mengistu and Bauer, 2011; Weinfurtner , 2001). As it is cited by Nciizah and Wakindiki (2015), from the works of different individuals and institutions in Ethiopa, Yields of crops from composted plots were 3 - 5 times higher than those treated only with chemicals. Studies conducted in Tigray also showed compost increased the grain yield of crops by 110% (Wassie , 2016). There is no wonder that organic soil amendments such as compost produced higher yield of crops because they are the sources of multiple nutrients required by plants or crops for their growth and developments. But , yield attained is different based on types of compost (fresh and finished compost) and amounts of compost applied (Weinfurtner, 2001). This increase in yield can be attributed to the effect of nitrogen. Studies also showed that the application of compost could influence the quality of plants. Application of compost could increase the amount of crude protein from 10.6 % up to 13.2 % at different rates of application and positive changes in plant quality with an increasing amount of gluten in wheat after compost treatment (Weinfurtner , 2001).

In the present Ethiopia , increased productivity in the agricultural sector has been constrained by high population pressure, deforestation and resource base degradation, soil erosion and soil fertility depletion (Workneh, 2015 ; Mengistu and Bauer, 2011; Shiferaw and Holden, 1999). In order to enhance sustainable agricultural productivity, the current farm land management practices need to be changed.

The decline in soil fertility was partly compensated by increasing arable land at the expense of forests, bush and grazing land or by putting cropland under fallow. However, in highly populated areas (e.g., the highlands), this alternative is no longer a possible alternative since land suitable for conversion to cropland is becoming scarce. Long fallow periods are no longer an alternative due to small and continuously decreasing farm sizes associated with population growth (Workneh, 2015;Shiferaw & Holden, 1999; Kebede, Y. et al 1990;).

A more sustainable management of the soil resource can be achieved through improved agricultural management such as crop rotation with nitrogen fixing legumes, addition and recycling of nutrients and erosion control. Direct addition of nutrients can be done through mineral fertilizer or organic inputs such as manure and compost, or through combination of both nutrient sources (Workneh, 2015; Eric , 2015; Mengistu and Bauer, 2011). Nitrogenous fertilizers are the most widely used fertilizers and deliver huge benefits in terms of productivity, especially in nutrient-depleted soils. However, these fertilizers also have a high potential for environmental damage in terms of GHG emissions and nitrate pollution (FAO,2013) .

Even if , there is no ample information available in Ethiopia on the effects of composting on carbon sequestration, the notable report as it is cited by Wassie (2016) is the work of Mulugeta et al. (2011) . The research was conducted to investigate the effects of compost on soil carbon stock compared to untreated check (control) and that of fertilizer treatments for three years at Arsi Negelle, Ethiopia. They found that compost treatment resulted in carbon sequestration by 0.15 and 0.25 t/ha in the year one and year two respectively as compared to the initial soil C stock whereas there was a loss of carbon by 0.0027 t/ha in the first year and 0.06 t/ha in the second year.

2.5.1.2 Determinants of composting

Composting ingredients are freely available but labour intensive in transportation and application. As a result, the choice between the two is mostly based on labour endowments and income levels of the farmers. (Wassie ,2016; Mengistu and Bauer, 2011). Labour availability can be measured as the proportion of household members who contribute to farm work. Using a binary logit, Odendo *et al*. (2009) found that the proportion of household members available to provide labour positively influenced adoption of soil fertility management practices.

According to Kilcher (2007), the greatest constraints faced by poor farmers on the road to organic soil management practices such as composting are lack of knowledge, access to markets, certification, agricultural inputs and lack of organization. According to FAO (2013), the global experience depicted that the main constraints of composting adoption are; Cost, limited access to technology and information. However, the specific barriers to adoption of compost and extent of adoption of compost production and uses vary from location to locations (Kassie et al., 2009) due to variation in agroecology, climate, socioeconomic condition, level of training and extension service provided to famers etc. For instance Kassie et al. (2009) studied the determinants of adoption of compost in semi-arid Tigray region of Ethiopia and reported both plot level and socioeconomic characteristics are important in adoption decision. According to the authors' young people, households that have access to extension service (aware), availability of sufficient labor in the household, being literate and having enough livestock positively impact the adoption of compost in the study area which is consistent to other results (Wassie , 2016).

Consistent with results from (FAO , 2013; Eric G.,2012; Kassie et al. 2009; Kilcher, 2007), according to Wassie (2016), the most widely recognized and crucial barriers to the adoption of compost by Ethiopian farmers are lack of skills, shortage of ingredients and lack of labour force for compost preparations. Compost production requires some kind of skills and knowledge on methods of compost production techniques which most famers are lacking it.

A few farmers are not willing to adopt composting because of offending foul smell released from the oxidation process. In some places farmers complain that volatile acids and gases released during turning of composts causes a variety of health problems.

2.5.2 Mulching

Mulch is an old age practice, simply mean a protective layer of a material that is spread on top of the soil. Mulches can either be organic--such as grass clippings, straw, dry leaves, bark clippings, saw dust, and similar materials — or inorganic—such as gravel, pebbles and crushed stones, brick chips, and plastic (NASD ,1998). The word mulch has probably derived from the German word "molsch" means soft to decay, which apparently referred to the gardener's use of straw and leaves as a spread over the ground as mulch (Shirish P.S et al, 2013). Apart from classifying mulching as organic and inorganic, there are different ways of classifying methods in mulching. Among them to list few: Surface Mulching- Mulches which are spread on surface to reduce evaporation and increase soil moisture, Vertical Mulching- which involves opening of trenches of 30 cm. depth and 15 cm. width across the slope at vertical interval of 30 cm. , Polythene Mulching- Sheets of plastic are spread on the soil surface between the crop rows or around tree trunks, Pebble Mulching- Soil is covered with pebbles to prevent transfer of heat from atmosphere, Dust Mulching- Interculture operation that creates dust that breaks continuous capillaries, and deep and wide cracks thus reducing evaporation from the exposed soil areas and Live Vegetative Barriers- Subabul and Glyricidia when used as live vegetative barriers on contour key lines not only serve as effective mulch when cut and spread on ground surface but also supply nitrogen to the extent of 25 to 30 kg per ha, besides improving soil moisture status (Weldemariam , 2017; Shirish P.S et al, 2013). Among the different types of mulch, mulching with vegetative residues has been considered one of the most effective at reducing the soil erosion rates and water losses in agricultural lands (Prosdocimi et al , 2016).

2.5.2.1Mulching as CSA practices

The world has experienced that in the intensive agricultural scheme of the green revolution , high agricultural yields are attained by heavy use of fertilizer and pesticides. But today it is realised that the green revolution prescription of poor agricultural yield are polluting the environment and degraded our soils. So, to add nutrients to our soils, to maintain a good micro-flora and a fine balance of micro-organisms in the soil, to conserve the moisture in the soil and to control the weeds in our fields, practicing mulching is becoming a solution (Prosdocimi et al , 2016).

Field researches have been revealed that mulch protects the soil from erosion, reduces compaction from the impact of heavy rains, conserves moisture, reducing the need for frequent watering, maintains a more even soil temperature, prevents weed growth, keeps fruits and vegetables clean, keeps feet clean and allowing access to garden even when damp provides a "finished" look to the garden (Weldemariam , 2017; Prosdocimi et al , 2016; NASD ,1998).

Soil erosion is a major environmental and agricultural problem facing human beings (World Economic Forum, 2010). The agricultural sector is known to be affected by higher erosion rates than other sectors because of several factors, such as conventional ploughing, low vegetation cover, soil compaction and sealing by heavy machinery, an absence of soil erosion control measures and the use of pesticides and herbicides that damage biological activity in soils and slope of farm land (Prosdocimi et al , 2016). In Ethiopia, a number of researches agreed that 50% of its highland areas have significant soil erosion, 25% of it was highly eroded and 4% of it is seriously eroded beyond reclamation (Daniel and Mulugeta ,2017; Aklilu ,2006). Any practice that help to reduce soil erosion such as mulching leads raising up of agricultural productivity. Mulching boosts the yield by 50-60 per cent over no mulching under rainfed situations (Prosdocimi et al , 2016). Researches also indicate that the yield of potato was the highest under paddy straw mulch (27.9%) and also starch content was highest in paddy straw mulch (18.18%) than unmulched plot (Shirish P.S et al, 2013; Weldemariam Seifu et al ,2017). Mulching restores soil carbon through decomposition and enhance mitigation(FAO,2013).

2.5.3 Agroforestry

Growing trees on farm land is an ancient skill for millennia. Farmers have nurtured trees on their farm, pasture lands and around their homes. This is why agroforestry is considered as ancient land-use farming practices around the world. It has been estimated to exist for more than 1300 years (Omarsherif and Daniel, 2017). Therefore, neither the concept nor the practice of agroforestry is new (Zinabu, 2015). As a scientific discipline the origin of agroforestry is fairly recent. Its modern scientific re-establishment thought goes to 1970’s. (Omarsherif and Daniel, 2017).

Essentially, agroforestry allows farmers to produce several goods and services in the same unit of land in an integrated manner to address a broader array of demands. Since its modern scientific re-establishment, many definitions have been coined. Despite minor differences, agree on essential features characterizing an agroforestry system: (i) The presence of at least one woody perennial component and at least one annual crop or animal component; (ii) The components are deliberately managed or cultivated; (iii) The system generates more than one output; and (iv) interaction exists among components (Ibid). Based on this, the World Agroforestry Centre developed a working definition of agroforestry: " ... an ecologically based natural resource management system that integrates trees (for fibre, food and energy) with crop and/or animal on farms with the aim of diversifying and sustaining income and production while maintaining ecosystem services" (ICRAF, 2000).

According to FAO (2010:9), "Agroforestry is the use of trees and shrubs in agricultural crop and/or animal production and land management systems." Agroforestry systems and practices exist in many forms. Such as : including improved fallows, taungya (growing annual agricultural crops during the establishment of a forest plantation), home gardens, growing multipurpose trees and shrubs, boundary planting, farm woodlots, orchards, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and tree apiculture (FAO 2010; Gitonga and Mukoya, 2016). Studies showed that , the dominant agroforestry practices identified in rural Ethiopian households are : farm boundary, farm woodlot , homestead tree integration mainly with Eucalyptus camaldulensis and multistorey coffee systems (Tanga and Amare , 2016; Omarsherif and Daniel , 2017)

Agroforestry is an old agricultural activity traditionally practised in many parts of Ethiopia. The practice involves the integration of trees and shrubs into farmland either through planting or natural regeneration (FAO, 2016). In Ethiopia, integrating multipurpose trees with food crops and livestock in intimate association is an ancient activity . There are several types of traditional agroforestry practices in different parts of the country. Coffee shade based systems, scattered trees on farm lands, home gardens, woodlots, farm boundary tree planting, trees on grazing lands, etc for example are some of the known traditional agroforestry practices (Tanga and Amare , 2016). Traditionally the moringa tree is interplanted with sorghum and other crops in Konso, Omo, Burji, Sena and Mele woredas of SNNP Regional State (FAO, 2016).

As it is indicated by Zinabu (2015), traditional agro forestry practices in Yeku watershed northeastern Ethiopia as trees and shrubs in silvipastoral lands, trees on farmlands, trees along rivers, and trees in homesteads. Growing *Acacia albida* as a permanent tree crop, on farmlands with cereals, vegetables and coffee underneath or in between, is an indigenous agroforestry system in the Harrarghe highlands of Eastern Ethiopia. Such indigenous practices are considered as CSA proven practical techniques (FAO, 2016). Nevertheless, in order to strengthen and make the existing practice effective, identification of the determinants is required.

2.5.3.1 Agroforestry as CSA practices

Agroforestry has both biophysical and socio economic roles wherever it is practiced. The biophysical roles include enhancement of biodiversity, soil conservation and prevention of soil erosion by wind and water, improvement of soil fertility through fixation of nitrogen and protection as windbreaks/shelterbelts (Zenabu, 2015). Besides, increasing farmers' income and alleviation of poverty, creation of employment opportunity, provision of fuel wood, fodder and construction wood, provision of food and medicine are the socioeconomic roles of agroforestry (Tanga and Amare , 2016).

The importance of agroforestry practices in view of the three pillars CSA is presented as follow by FAO .

> Agroforestry help to tackle the triple challenge of securing food security, mitigation and reducing the vulnerability and increasing the adaptability of agricultural systems to climate change. Trees in the farming system can help increase farm incomes and can help diversify production and thus spread risk against agricultural production or market failures. This will be increasingly important as impacts of climate change become more pronounced. Trees and shrubs can diminish the effects of extreme weather events, such as heavy rains, droughts and wind storms. They prevent erosion, stabilize soils, raise infiltration rates and halt land degradation. They can enrich biodiversity in the landscape and increase ecosystem stability (FAO 2010: 9).

Practicing agroforestry fundamentally generate both economical and ecological benefits. Omarsherif and Daniel (2017) showed that, the three dominant agroforestry practices, i.e. multistorey coffee systems, homegardens, and multipurpose trees on farmland in south and south western Ethiopia contribute substantially to the food and nutrition security of households and communities. Crops cultivated under multipurpose trees on farmland produce the major annual food supply of the households, which is generally completed by homegardens that also generate supplementary income.

2.5.3.2 Determinants of agroforestry

Adoption of agroforestry practices like any other agricultural innovation practices is influenced by a number of physical, institutional and social factors. Studies identified : gender of farmers, land size, level of education, farmers' experience, farmers' association, contact with research and extension, land tenure, agro-ecological zone, distance to nearest center, and farmer's income as influencing factors in adopting agroforestry practices by rural farmers (Gitonga and Mukoya , 2016; Tanga and Amare , 2016).

According to a research conducted at Fogera district of north-western Ethiopia, Age, attitude land tenure security, erosion and training in natural resource management and/ or agriculture affects agroforestry practices significantly. Except Age the remaining four factors are affecting the practice positively (Tanga and Amare , 2016). A research conducted by Geremew (2016), at Mecha rural district of Amhara regional state revealed that, being male-headed household, family size, vulnerability of the plot to land degradation, the comparative economic incentive of cash tree plantation and farm size have positive effect on cash tree adoption; while non-food crop farming practices and experience of cash-tree plantation had an adverse effect on the agroforestry plantation practices.

2.6 Theories of Adopting Agricultural Technologies

The following three theories explain how, why, and at what rate new agricultural practices can be adopt by household farmers. (Negatua W. and Parikhb A. , 1999)

2.6.1 The economic constraints theory

The central assumption of this model, also known as the factor endowment model, is that the distribution of resource endowments among the potential users in a country/region determines the pattern of adoption of a technological innovation. The model assumes that market prices (induced by policy and institutional interventions) reflect the relative scarcity of the factors, implying the existence of (or need for) well-performing markets and the importance of price policies (Hayami and Ruttan 1971)

2.6.2 The technology characteristics-user's context theory

The technology characteristics-user's context theory integrates approaches which assume that characteristics of a technology under lying users' agro-ecological, socioeconomic and institutional contexts play the central role in the adoption decision and diffusion process (Biggs, 1990; Scoones and Thomson, 1994). This model can also consider the perceptions of potential adopters regarding the characteristics of a technology as a component affecting adoption decisions and hence the diffusion of the technology (Gouldet et al. 1989). The model implies the importance of the involvement of farmers in the technology development process with the aim of generating technologies with appropriate and acceptable characteristics. The model also implies the importance of institutionalisation of research policies and strategies that facilitate the participation of farmers and other relevant stakeholders in the technology development process.

2.6.3 The innovation-diffusion theory

The process of adopting new innovations has been studied for over 50 years, and one of the most popular adoption theory is described by Rogers in his book, Diffusion of Innovations, also called transfer-of-technology (TOT), follows from the initial work of Rogers 1962. According to this theory, a technology is transferred from its source (research systems) to final users through agent medium (extension systems) and its diffusion in potential user communities depends mainly on the personal characteristics of the potential individual user. This theory assumed that the technology is appropriate for use unless hindered by the lack of effective communication. This study is mainly depending on this theory.

2.6.3.1 Key elements in diffusion of innovations

According to Rogers (2003), innovation, communication channels, time, and social system are the four key components of the diffusion of innovations. The first one is *innovation*, an *innovation* is an idea, practice, or project that is perceived as new by an individual or other unit of adoption” (Rogers 2003: 12). An innovation may have been invented a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. The newness characteristic of an adoption is more related to the three steps (knowledge, persuasion, and decision) of the innovation-decision process. Second, *Communication channels*, diffusion, by definition, takes place among people or organizations. Communication channels allow the transfer of information from one unit to the other. Communication patterns or capabilities must be established between parties as a minimum for diffusion to occur. Third , *time* , the passage of time is necessary for innovations to be adopted; they are rarely adopted instantaneously. In fact, in the study on hybrid corn adoption, adoption occurred over more than ten years, and most farmers only dedicated a fraction on their fields to the new corn in the first years after adoption. The time is involved in (i) Innovation-decision process (ii) innovativeness and (iii) an innovation's rate of adoption (Ibid). Fourth , *Social system*, the social system is the combination of external influences (mass media, surfactants, organizational or governmental mandates) and internal influences (strong and weak social relationships, distance from opinion leaders). There are many roles in a social system, and their combination represents the total influences on a potential adopter . Rogers (2003: 23) defined the social system as "a set of interrelated units engaged in joint problem solving to accomplish a common goal". Since diffusion of innovations takes place in the social system, it is influenced by the social structure of the social system.

2.6.3.2 The innovation-decision Process

According to Rogers (2003) , adoption decision of new technologies involves five steps: (1) knowledge,(2) persuasion, (3) decision, (4) implementation, and (5) confirmation. These stages typically follow each other in a time-ordered manner. This process is shown in figure 4. At the knowledge step , Person becomes aware of an innovation and has some idea of how it functions. At Persuasion step ,person forms a favourable or unfavourable attitude toward the innovation. At decision step, person engages in activities that lead to a choice to adopt or reject the innovation. At Implementation step, Person puts an innovation into use and finally, at Confirmation step of adoption decision person evaluates the results of an innovation-decision already made. (Rogers 2003)

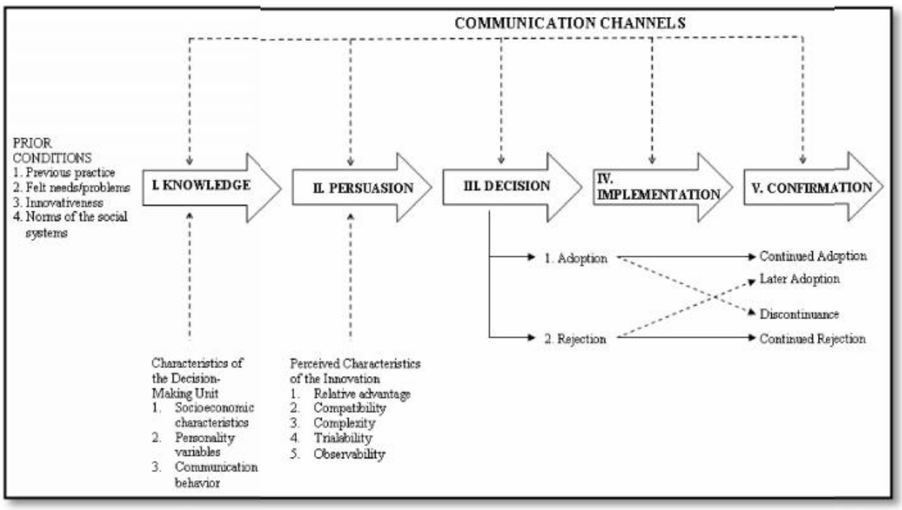


Figure 4. Model of Five Stages in the innovation-decision Process (adopted from Rogers, 2003 :170)

2.6.3.3 Adopter Categorization on the Basis of Innovativeness

Rogers (2003:22) defined the adopter categories as "the classifications of members of a social system on the basis of innovativeness". This classification includes innovators, early adopters, early majority, late majority, and laggards (Figure 5). In each adopter category, individuals are similar in terms of their innovativeness: "Innovativeness is the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system" (Ibid.).

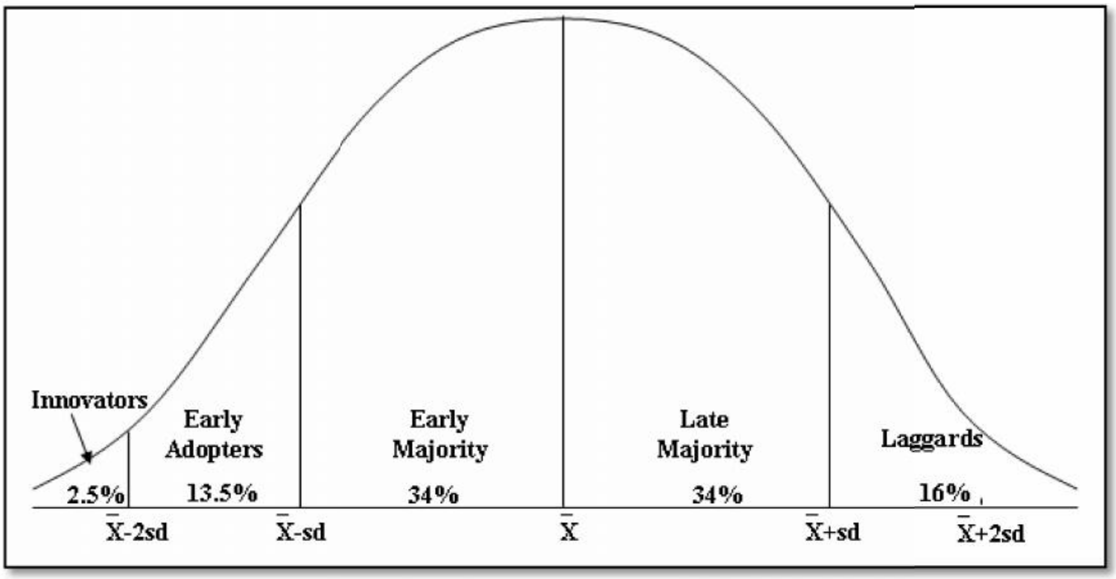


Figure 5. Adopter Categorization on the basis of Innovativeness (Rogers, 2003 :281)

- Innovator: Venturesome → interest in new ideas leads them out of a local circle
- Early Adopter: Respect → has highest degree of opinion leadership in most systems
- Early Majority: Deliberate → interact frequently with peers, 1/3
- Late Majority: Skeptical → pressure from peers, economic necessity, cautious,1/3
- Laggards: Traditional → possess no opinion leadership, isolates, suspicious of innovation

2.7 Conceptual Framework

Climate-smart agricultural practices can be developed and implemented to improve food security and rural livelihoods and simultaneously facilitate climate change adaptation and mitigation benefits. As it is indicated in Figure 6 , to attain these output, climate smart agricultural practices, such as: soil management ,water management and agroforestry practices must be exercised by household rural communities whose livelihood is mainly depend on agriculture in climate change prevalence situation.

The decision to adopt CSA practices or not is assumed to be determined by biophysical , socio-economic and institutional factors. It is assumed that these factors along with the farmer's awareness towards CSA practices influence the decision to adopt.

Farmers who adopt CSA practices are expected to have well maintained and sustainable fertile farms which enhance production of high yields and better climate adaptive capacity.
In addition, the effect of adoption will positively contribute to climate change mitigation due to reduced emissions, high stabilization of soil organic matter and increased soil water retention capacity.

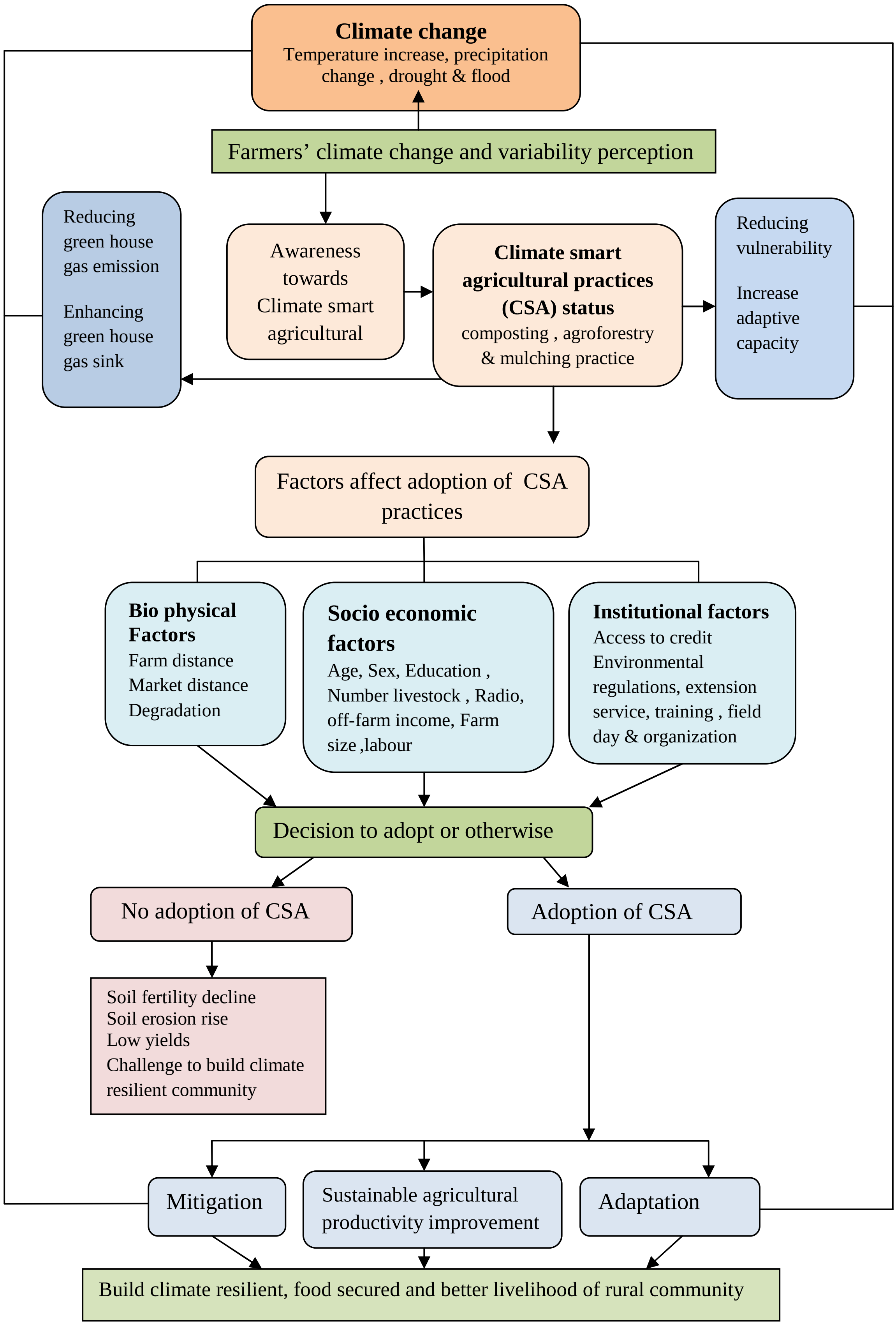


Figure 6. Study conceptual framework (Source: Author's conceptualization)

CHAPTER III
MATERIALS AND METHODS

3.1 Study area

The study was carried out in Gerar Jarso woreda, which is one of the woredas of North Shewa Zone of Oromia National Regional State (Figure 7). The woreda lies along the highway to Amhara National Regional State in the North western direction at a distance of 112 km from Addis Ababa. It shares border with Amhara Region in the North, Yaya Gullalle woreda in the East, Debre Libanos woreda in the South and Degem woreda in the West. The total area of the woreda is about 42763 hectare. The altitude of the woreda ranges from 1300 to 3419 meters above sea level. Geographically, the woreda lies 9°38'47"N to 9°59'49"N and 38°34'17"E to 38°49'41"E. According to Fiche Station meteorological data the average rainfall amount of the woreda is about 1200mm, and maximum and minimum rainfall is about 1115mm and 651mm, respectively. Temperature of the woreda ranges from a minimum of 11.5 ^{0} c to a maximum of 35 ^{0} c . The 2007 national census reported a total population for this woreda of 67,312, of whom 34,467 were men and 32,845 were women. (CSA, 2007). Girar Jarso woreda dominantly consists of people with two ethnic groups, Oromo and Amhara. The majority of the people, 75 percent in the area belongs to Oromo ethnic group while the rest 25 percent belongs to the Amhara ethnic group. With regard to religion, almost all (99.81%) of the population of the woreda are believers of Ethiopian Orthodox Tewahodo Christianity (Meskerem, 2011).

The land topography is characterized by plain , mountains, sloppy to steep sloppy and gorges. About 36 percent of the land area is plain while the proportion of the total area that is considered as sloppy is about 33 percent. The remaining 31 percent is classified as mountainous and gorges. Agro-ecologically, the woreda is categorized into three: *Dega, Woina Dega* and *Kolla* (Motuma, 2017). Among the seventeen kebeles; 8 are *Dega* , 7 are *kolla* and 2 kebeles are *Woina Dega.* The types of soil in the study area are Vertisols covers about 58% of f the total cultivated land., Nitisols comprises about 14 % of the cultivated soils of the cultivated soils , Cambisols 11%, and other type of soil is 13%, Leptosols accounts for about 14% of the total cultivated land, Luvisols in GerarJarso covers about.6% of the cultivated land and intensively cultivated soils , Fluvisols is about 5% and Cambisols cover about 3.4 .% of the cultivated land of the Girar Jarso (Engdawork, 2015).

With regard to land use pattern, cultivated land covers the largest share, 71 percent (37006 ha) while grazing land is the second largest land use pattern that covers 16 percent (7910). About 1.62 percent (739.4 ha) Forest land, 1.64 percent (813 ha) Construction land, Bushes land 0.24 percent (122 ha), Land for Park 0.oo percent (1.622ha) , Unproductive land 5.5 percent (2720ha) and Others 0.24percent (123ha) of the total 49435ha of the woredas' land area (GJARDNO, 2014).

The main economic activity of the population of the woreda is mixed farming at subsistence level producing both crops and livestock. Farming is main livelihood strategy of the woreda in which seasonal rain fall pattern determined the production activity. More than 90% of the population depends on subsistence farming as livelihood strategy. In Girar Jarso woreda , *belg* crop production accounts 14% while, *meher* crop production accounts about 86% . Hence, *meher* crop production is the major livelihood strategy that people engaged in (WAO,2015). The major crops produced in the woreda include: Cereals crops such as teff (Eragrostis tef), wheat ,barley, maize and sorghum , horticultural crops such as fruits, vegetables, root crops, pulses include bean, peas, field pea, lentils and vetch. Besides, oilseeds such as linseeds and *nug* (*Guizotia abyssinica*) are growing. Agricultural products are consumed at home and partly sold to earn cash to meet other household needs, educate children, and contribute to social affairs (Motuma, 2017).

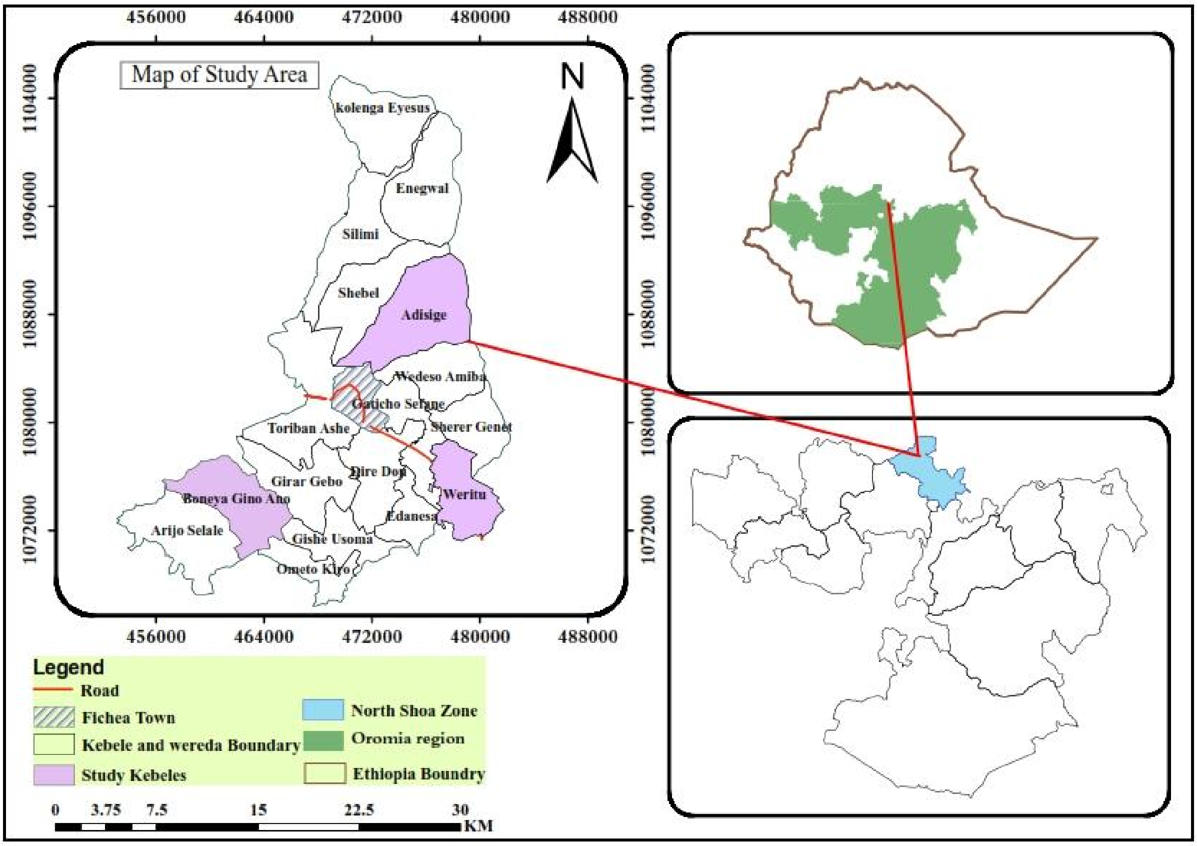


Figure 7. Location map of Gerar Jarso woreda (Source: CSA/2007)

3.2 Sampling and Sample Size

The population of the study consist smallholder rural farmers in Gerar Jarso woreda of Oromia region who are living in 8 *dega* , 2 *woina dega* and 7 *kola* kebeles. In order to represent the population with sufficient accuracy and to infer the sample results to the population, the target sample households were selected in a purposeful multistage stratified sampling process. In the first stage, 17 kebeles were stratified into three based on agro-ecological zones. In the second stage 4 kebele administrations (KAs) were purposefully selected among a three agro ecological strata based on socio economic, infrastructural accessibility, time, agro- ecology and other physical factors status of the kebeles to carry out CSA practices (Table 4). In the third stage, among the 4 ones, 204 household were randomly selected for household survey. This number of KAs in the study site was considered to be sufficient for statistical analysis and convenient to be surveyed with the available resources of finance, human and time.

The randomly selected households sample sizes for each KA were determined based on their household heads proportion.

Determination of the sample size was based on the formula given as shown below:

$$n_r = \frac{z^2 pq}{d^2}$$

where; $\mathbf{n_r}$ is the sample size, **z** is 95% confidence level (α= 0.05) is $1.96^2 = 4$, **p** is the proportion of the population of interest, smallholder farmers. Variable **q** is the weighting variable and this is computed as **1-p** , and **d** is an acceptable error (precision). **p** was set to 0.5 since statistically, a proportion of 0.5 results in a sufficient and reliable size particularly when the population proportion is not known with certainty. This led to **q** of 0.5 (1- 0.5). An error of less than 10% is usually acceptable (Kothari, 2004) thus, the study took an error of 0.07 to approximate a sample size of 204 household survey respondents. (i.e $4*0.5*0.5/0.07^2 = 1/0.0049 = 204$)

From the total of 204 questionnaire distributed to the enumerators 201 (98.5%) were completed and returned. Table 4 shows, the number of respondents in sampled kebeles.

Table 4. Kebele administrations and number of household heads selected for the household Survey

Name of sample KA*	Total number of households in KAs					Number of households sampled** in KAs	Agro-ecology
	Male-headed		female-headed				
	Number	%	Number	%	Total		
Wertu	447	85.4	78	14.9	525	36	Woinna dega
Adisge	823	82.1	180	17.9	1003	69	Kola
Gino	537	85.9	88	14.1	625	43	Dega
Eyeta	750	97.7	18	2.3	768	53	Dega
Total	2557	87.5	364	12.5	2921	201	

* KA - Kebele Administration - the smallest administrative unit in Ethiopia ** Sample proportion = 0.068

(source : Field Data)

Respondents of focus group discussion and key informant interviews were selected purposively guided by factors such as age , gender , social networks, accessibility and the level of farmer’s and agricultural development agent’s willingness to respond.

3.3 Data type

The study gathered both primary and secondary data . The primary data were obtained by using :a survey questionnaire, Focus group discussion, key informant interviews and transect walking. The secondary data sources such as meteorological data of the study area, various reports, proclamations and other documents were used to reinforce the data collected from the primary sources.

3.4 Data collection instruments

3.4.1 Household survey

Questionnaires were distributed for 204 household farmers to the study woreda who are living in four kebeles, in order to assess: the patterns and trends of climate variability, perception of farmers in CSA practices and significant factors in adopting CSA practices. The question items are both open ended and closed ended type. They originally prepared in English and latter translated to Affan Oromo and Amharic which are the widely spoken languages of the sample kebeles. The survey was conducted by four enumerators (one for each kebele) after being trained on data collecting procedure and content of the instrument by the researcher.

3.4.2 Focus group discussion (FGD)

FGD was employed to collect first hand information on climate variability and the nature, practices, challenges and implementation of CSA practices. Besides, FGD was conducted to assess farmers perception on CSA practices. Focus group discussants were purposively selected in order to be representatives of different social groups and to get their long years of experience on climate smart agricultural practices of their kebeles. Accordingly , five focus group discussions which consist of 6-9 individuals were held across the sample kebeles. The purpose of the focus group discussions was to generate in depth information on some of the survey findings and other issues that may not have been adequately captured by the structured questionnaire survey.

3.4.3 Key informant interview (KII)

six key informant interviews were made with selected female and male headed households in order to get information about their awareness to climate change, impacts of climate change and CSA practices adoption to adapt and mitigate climate change adverse impacts. Likewise, four agricultural development agents from the sample kebeles and two experts at

Gerar Jarso woreda agricultural and natural resource bureau were interviewed to collect primary information about awareness , challenges and adoption of CSA practices among rural farmers..

3.4.4 Transect walking

Transect walk with photograph camera was made by the researcher to identify the farmer's landmarks, soil and water management patterns, agroforestry practices , socio-economic indicators and resource endowments. The route to follow on the walk was selected randomly within the study kebele. The walk also includes random visits of selected farms and discussions with farmers. The transect walks provided validating information received through key informant interview and/or focus group discussions.

3.5 Data Analysis

The bio physical, socio economic and institutional data that was collected using questionnaires from the selected 201 household farmers were analysed by using descriptive statistical analysis including frequency distribution, percentage, mean and standard deviation (SD). And also, regression analysis using logit model was employed to identify determinant factors that influence the adoption of CSA practices by rural famers using computer software programme called statistical package for social sciences (SPSS version 20.0). Also, specific characteristics of the variables and results were presented in tables, graphs and charts.

The qualitative data collected by employing open ended questions, FDG, key informant interviews and direct observation by transect walking were used along with quantitative data as supplement to support and elaborate the findings.

3.6 Model Specification

The two computing models commonly used in the adoption studies are the probit and logit models. The models are popular statistical techniques in which the probability of a dichotomous outcome (such as practicing or non-practicing) is related to a set of explanatory variables that are expected to influence the outcome. But the results obtained from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar. There is no compelling reason to choose one over the other. In practice many researchers choose the logit model because of its comparative mathematical simplicity (Gujarati and porter, 2009: 571). Logistic regression also referred to as logit model has no assumptions about the independent variables: they do not have to be normally distributed, linearly related or of equal variance within each group (Tabachnick BG, 2007). Due to its computational simplicity and other statistical advantage logit model is employed in this research paper.

Following (Gujarati and porter, 2009) the logit model can be specified as:

$P_i = E(Y_i = 1/X_i) = F(\beta_0+\beta_i X_i)$ (1)

$$= \frac{1}{1 + e^{-(\beta_0+\beta_i x_i)}}$$

$= \frac{1}{1+e^{-z_i}}$, where $z_i = \beta_0 + \beta_i x_i$

$= \frac{e^{z_i}}{1+e^{z_i}}$ ……… is the cumulative logistic distribution function (2)

Where $P_i = P(Y= 1)$ is the probability that the farmers adopt CSA practices

X_i = are different factors that affect farmer's adoption decision

β_0 = is the constant term.

β_i' s = are the coefficient of parameters.

In the estimation of the model , the probability of non – adoption is given by :

$1 - P_i = \frac{1}{1+e^{z_i}}$ (3)

And the odd ratio which tells the ratio of the probability of the farmer will adopt CSA practices to the probability the farmer will not adopt the practices can be written as :

$$\frac{p_i}{1 - p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \qquad (4)$$

Hence ,

$L_i = \ln [\frac{p_i}{1 - p_i}] = Z_i = \beta_0 + \beta_i x_i$, where, L_i is the log of the odd ratio. (5)

Also,

$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i + e_i$ (6)

Taking the natural logarithms of the odds ratio of equation (4) will result in what is called the logit model as indicated below.

$\ln [\frac{p_i}{1 - p_i}] = \ln [e^{\beta_0} + \sum_{i=1}^{n} \beta_i X_i] = Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + e_i$ (7) (e_i is the error term with zero mean and constant variance.)

In this research the logical function (7) is applied to model the independent variables. where Z_i denotes the probability of the i^{th} farmer to adopt the CSA practices. β predicts the log odds of the dependent variable.

The model is explicitly expressed as follows:

$Y_i = \beta_0$ (±) $\beta_1$age (+) β_2 sex (+) β_3 family size (+) β_4 active labour force (+) β_5 education (+) β_6 farm size (-) β_7 number of parcels (-) β_8 average farm distance from homestead (-) β_9 average farm distance from the proxy market (-) β_{10} average farm distance from the main road + β_{11} degradation + β_{12} number of livestock + β_{13} access to credit + β_{14} radio + β_{15} access to weather forecasting + β_{16} Off-farm income + β_{17} knowledge on Environmental regulations + β_{18} extension service + β_{19} training +β_{20} Organization + β_{21} farmer's field day participation +ε_i (The signs in the bracket indicate the expected signs in the predicted model)

Table 5. Expected signs (hypotheses) of the independent variables

Independent variable	Expected sign	Rational
Age	Negative or positive	Older farmers are highly risk averse and less adopters of CSA practices (Wang Na et al,2016; Assefa and Gezahegn , 2004 and Ashenafi , 2006). While other studies revealed that number of years of experience in agriculture affect adoption of improved agricultural technologies positively (Kebede et al. 1990)
Sex	Male +ve Female -ve	Since, the allocation of resources in the community is biased towards males, they are expected to be better adopters. (Legesse ,1998)
Family size	Positive	Hence, a large family size is a source of labour for agricultural practices , family size is positively correlated with adoption decision.
Labour force	Positive	If a family is endowed with active working age members it is encouraged to adopt labour intensive climate smart agricultural practices.
Education	Positive	Education enables farmers to distinguish more easily technologies whose adoption provides an opportunity for net economic gain. (Garcia et al 2016; Robera, 2013)
Farm size	Positive	Farmers with large farm size can Adopt new practices on some part of their land and evaluate the benefits of adoption (Wang Na et al ,2016 ; Ashenafi , 2006 and Robera , 2013).
Number of parcels	Negative	If number of parcels increase farmers' couldn't have sufficient time and energy to adopt climate smart agricultural practices.
Degradation	Positive	Degradation is expected to be positively associated with adoption as farmers are aware that soil degradation could cause yield reduction (Shiferaw and Holden ,1998).
Farm distance from market	Positive	Since markets provides inputs for CSA practices , farmers who are more proxy to market areas are more adopters.
Farm distance from homestead	Negative	The average time the farmer must travel from the residential area to the plots has an effect on the status of soil conservation and rehabilitation practices. So, the further away the plots, the less effort employed in maintaining soil fertility .
Farm distance	Negative	Farmers near to the main roads minimize the transaction costs of

from the main road		buying inputs and selling products . Therefore , they could be more adopters than those who are living far from the main roads.
Number of livestock	Positive	Livestock provide animal excrement which is primary input for the preparation of compost and mulch. Therefore, livestock owners are expected to adopt composting and mulching more likely than non-owners (Robera ,2013).
Access to credit	Positive	Farmers having credit access are better adopters since they will have money for easy access to have CSA practices . (Legesse ,1998 and Ashenafi , 2006)
Off-farm income	Positive	Off farm Income - represents the amount of other incomes the farmer obtained other than Farming. It is expected to contribute positively in the adoption process. (Kebede et al, 1990 and Ashenafi , 2006)
Radio	Positive	Radio is assumed to give information about best practices to farmers and hence affect the adoption decision positively. (Wang Na et al ,2016; Garcia et al 2016 and Ashenafi , 2006)
Training	Positive	Farmers who have access to training tend to be more progressive and receptive to climate smart agricultural practices. (Workenh, 2015)
Farmer’s field day	Positive	Since, farmer’s field day enhance farmers’ to learn by watching , participants are more CSA adopters than non-participants .
Environmental regulations	Positive	The stringency of Environmental regulations could affect farmers’ adoption decisions positively. (Wang Na et al ,2016)
Extension service	Positive	Farmers having extension contact knows the source and possible benefit of the technologies. (Assefa and Gezahegn , 2004 and Ashenafi , 2006)
Access to weather forecasting	Positive	Having weather forecasting information affects adoption of climate smart agricultural practices positively (de Jalon et al .2016).
Organization	Positive	Cooperative organizations and rural assciations which are supported by government to offer farmers credit support services, technological training services, etc. Motivate their members to adopt CSA practices. (Wang Na et al ,2016)

Table 6. Description of variables used in the logistic regression model.

Variable Name/CODE	Description	How variable was inputted
DEPENDENT VARIABLES		
ADCOMP	Adoption of compost by household farmers	Dummy, 1= adoption, 0= not adoption
ADAGRO	Adoption of agroforestry by household farmers	Dummy, 1= adoption, 0= not adoption
ADMULCH	Adoption of mulch by household farmers	Dummy, 1= adoption, 0= not adoption
INDEPENDENT VARIABLES		
DAGE	Age of the household head	Continues variable , year
DSEX	Sex of the household head	Dummy, 1= male , 0= female
LABOR	Labor force proportion	Continues variable , %
FAMSIZE	Family size	Continues variable , Nu
DEDUC	Education level of the household head	Dummy, 1= elementary and above 0= illiterate
PLOTNR	Number of parcels (farm plots)	Continues variable, Number
FRMSIZE	Farm size	Continues variable, hectare
FRMDIST	Average home distance from the farm plot	Continues variable, (in min)
DDEGRAD	Degradation	Dummy, 1= degraded, 0= otherwise
MKTDIST	Average home distance from market	Continues variable, (in min)
RDDIST	Average home distance from the main road	Continues variable, (in min)
DLIVSTOK	Livestock number	Continues variable, (TLU)*
DOFFARM	Having additional Off farm(Non-farm) income	Dummy, 1= having off farm income, 0= otherwise
DEXTSERV	Having extension service in 12 months	Dummy, 1= contacted by extension agent more than three times per year, 0= otherwise
DTRAING	Having agro-technical and CSA practices training	Dummy, 1= trained, 0= otherwise
DRADIO	Availability of Radio	Dummy, 1= having radio, 0= otherwise

DWEATHER	Access to weather forecasting	Dummy, 1= having access to information on weather forecasting , 0= otherwise
DFIELDAY	Farmers' field day participation	Dummy, 1 =participated in farmers' field day, 0= otherwise
DORGANZ	Membership in farmers' organizations	Dummy, 1= if registered, 0= otherwise
DCREDIET	Access to credit	Dummy, 1= having credit access , 0= otherwise
DENVREGU	Knowledge of environmental regulation	Dummy, 1= having knowledge of environmental regulation , 0= otherwise

* Tropical livestock unit (TLU) ratio approximate weight, subsistence (food) and market value of different animals. They are universally used in the following manner: 1 TLU=1 head of cattle (oxen, bull, cow, calf heifer), 0.5 TLU=1 horse/donkey/mule , 1.4 TLU=1 camel ,0.1 TLU=1 sheep/goat and 0.05 TLU=1 chicken (Land O'Lakes International Development, 2007).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents findings from the study and is divided into six sections. The first section presents background information on respondents. The second section presents results on pattern and trends of climate variability in Gerar Jarso woreda . The third section presents results of smallholder farmers perception towards CSA in in the study woreda. The fourth section presents types and characteristics of CSA practices carried out by smallholder farmers in Gerar Jarso woreda. The fifth section presents results of the logistic model estimation of the explanatory variables of CSA practices adoption. The model result describes the characteristics of three dependent variables: such as mulching, composting and agroforestry. The six section describes constraints to adopt CSA practices.

4.1 Demographic and Socio -Economic Characteristics of Respondents

As shown in Table 7 , males are predominant household heads (88.1%) respondents in the study area. A family size greater than 5 accounts a bit more than half of the sample households in Gerar Jarso woreda (52%). Compare to the national statistics estimation of average household size of 5 at nationwide (CSA ,2007), the study woreda is the one which is endowed with a large family size per household. The education level of respondents was mainly illiterate (63.2%) who are unable to read and write. First cycle primary, second cycle primary and high school was 24%, 8% and 5% of respondents respectively. The results of this study are nearly in accord with those of Wang (2016), which revealed that farmers had higher ages and lower education levels in developing countries. And also agreed with studies conducted in Ethiopia by (Ashenafi , 2006; Meskerem, 2011)

All most all farmers in the study woreda are engaged in crop production dominant mixed farming activity (98.5%). Two- third of the rural farmers have 3-4 farm plots with farm size less than 2.1 hectare.

Table 7. Background information on respondents ($n^* = 201$)

Variable		Number	Percentage (%)
Household marital status			
	Single	1	0.5
	Divorced	2	1.0
	Married	191	95.0
	Widowed	7	3.5
Household head sex			
	Female	24	11.9
	Male	177	88.1
Family Size			
	1-3	22	10.9
	3-5	73	36.3
	6-8	86	42.8
	greater than 8	20	10.0
Education			
	illiterate	127	63.2
	Grade 1-4	48	23.9
	Grade 5-8	16	8.0
	Grade 9-12	10	5.0
Farming occupation			
	Mixed with crop dominance	198	98.5
	Mixed with livestock dominance	3	1.5
Farming Year			
	1-10	8	4.0
	11-20	52	25.9
	21-30	79	39.3
	greater than 30	62	30.8
Number of farm plot (parcel)			
	1-2	43	21.4
	3-4	132	65.7
	5-6	22	10.9
	greater than 6	4	2.0

Farm size in hectare			
	less than 1	60	29.9
	1-2	71	35.3
	2.1-4	64	31.8
	greater than 4	6	3.0

* denote total number of respondents

(Source : computed from field data)

4.2 Trends of Climate Variability and Change

4.2.1 Trends of temperature change in Gerar Jarso woreda

Since, mean annual temperature rises through time, the variability of temperature in the study woreda is characterized by an increasing trend (Figure 8). The mean temperature in the study area ranges from 9.3^{0}C (minimum) to 21.3 ^{0}C (maximum) with annual average temperature of 14.3 ^{0}C. Using a linear regression model, the rate of change is defined by the slope of the regression line (Fig. 8) which in this case is about 0.27, 0.38 and 0.16 C per decade for mean, maximum and minimum temperature respectively. The rising up of temperature in the last five years is higher compared to previous years. The standard deviation of average temperature from the mean for the last 30 years (1987-2017) is 0.39. The figure depicts the existence of warming trend in the study area. The situation is agreed with the national climate change assessment and prediction. According to UNDP, mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade. The increase in temperature in Ethiopia has been one of the most rapid at a rate of 0.32°C per decade. According to USAID (2012), if recent warming trends continue, most of Ethiopia will experience more than a 1.0° Celsius (°C) increase in air temperature , with the warming tendency projected to be greatest in many part of the country. This warming will intensify the impacts of droughts, and could particularly reduce the amount of productive crop land and exacerbate food insecurity among rural farmers. So the situation enforces to apply agricultural practices that enhance mitigation and improve adaptive capability of farmers, i.e. CSA practices.

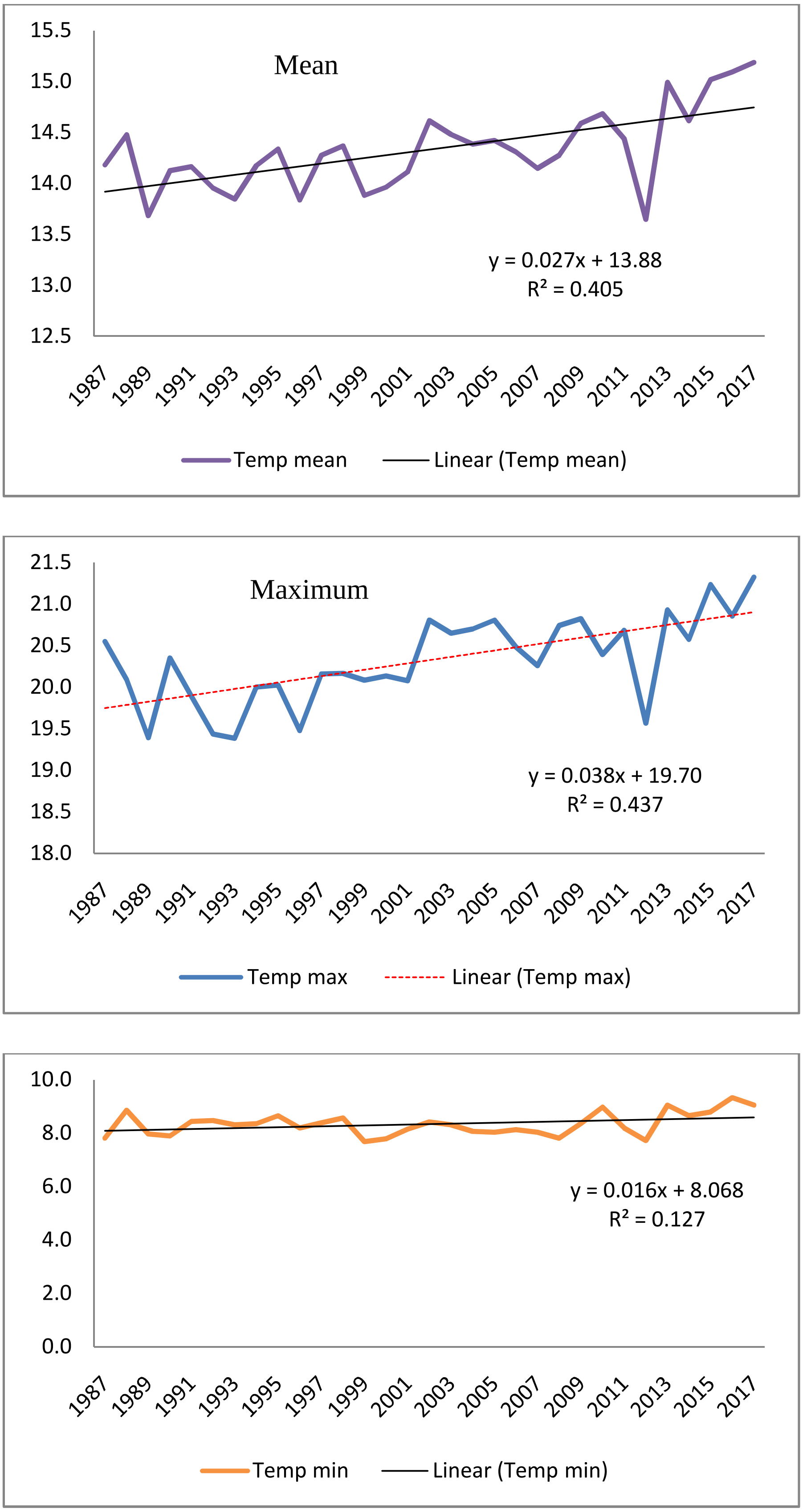


Figure 8. Temperature pattern (Mean, Maximum and Minimum) of Gerar Jarso woreda (1987–2017) with linear least square regression lines. (source : computed from NMA meteorological data)

4.2.2 Trends of precipitation change in Gerar Jarso woreda

The mean annual rainfall of Gerar Jarso woreda during the study period was 1149.4 mm with 123.56 mm standard deviation and 10.75% CV. The minimum and maximum ever recorded rainfalls were 910.8 mm (in 2015) and 1539.30 mm (in 1996) respectively. Even if ,there is no clear trend in total annual rainfall observed at national level (Belay, 2016), the local meteorological data reveals constant trend with insignificant increment of annual rainfall in the study area with a slope of 0.774 of the linear trend line (Figure 9). From the computed coefficient of variation (CV= 10.75%), it is observed that rainfall variability is less in the study area. According to Hare (2003), CV is used to classify the degree of variability of rainfall events as less (CV < 20), moderate (20 < CV <30), and high (CV >30). As indicated in Table 8, decadal mean rainfall amount declines by 1.7 % when we go from 1st decade to the 2nd . However, decadal mean rainfall rises by 2.3% in the recent decade. So, there is inter-annual and inter decadal variability of rainfall in Gerar Jarso woreda.

Table 8 Mean rainfall amount of Gerar Jarso woreda per decade

Decade	Years cover	Mean rainfall (in mm)	Percentage change
1	1987-1997	1153.6	-
2	1998-2007	1133.7	-1.7
3	2008-2017	1160.3	0.023

(source: computed from NME data)

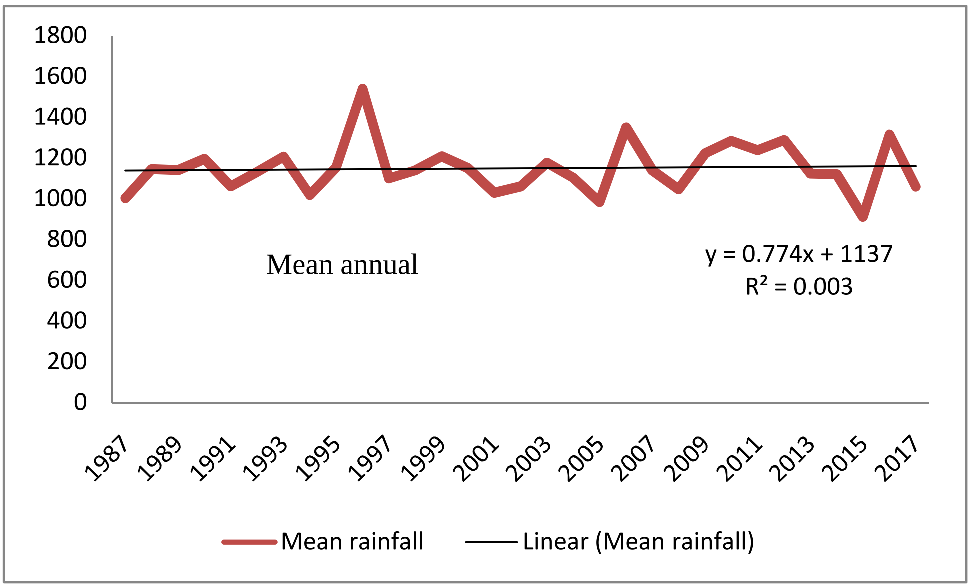


Figure 9. Annual rainfall pattern of Gerar Jarso woreda (1987-2017) (source : computed from NMA meteorological data)

The changes in the timing and distribution of precipitation leads for a rising frequency of both extreme flooding and droughts. The two disaster risks seriously affect the production and food security of the study area. Mainly drought through water shortage causes adverse impacts on vegetation, animals, and/or people. The meteorological drought which is highly linked to agricultural drought is sufficient to markedly increase the number of poor harvests, unless sustainable agricultural production practices are promoted.

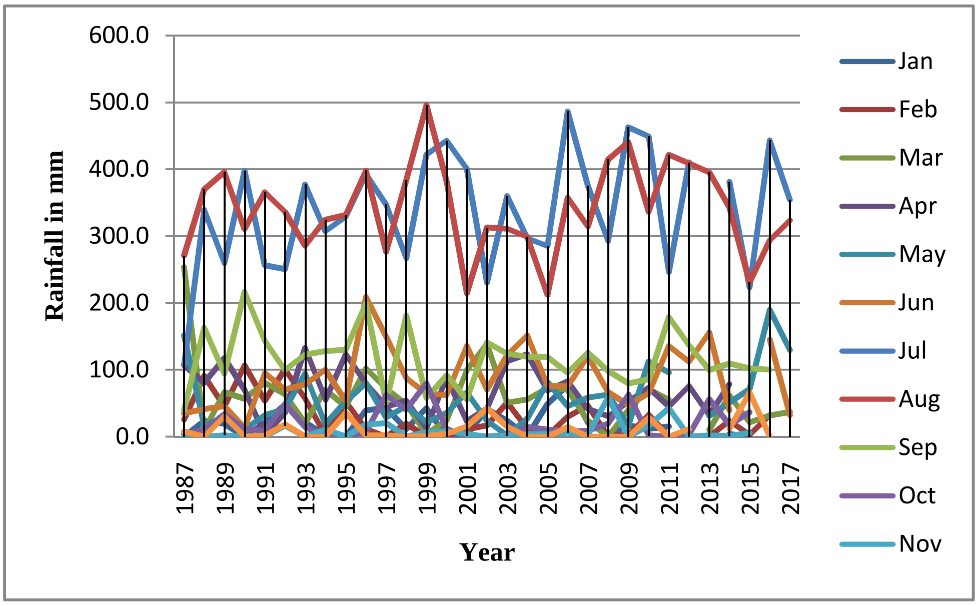


Figure 10. Gerar Jarso woreda monthly rainfall distribution (source: computed from NMA meteorological data)

There are two main seasons in the study area locally called *Genna and Bona* : *Genna* is a main rainy season like other Ethiopia highlands which extends from June to September (Figure 10) and *Bona* the period that extends from October to May. The *Genna* rains are used for planting both long and short cycle crops (Engdawork ,2015). Rainfall amount variability and shortage was critical in the main rainy season of the study area for the past five years (2013-2017) (Figure 11). The situation tends to affect the livelihood of thousands in the study woreda. Ground realities revealed that, deficiency in precipitation brought crop production shortages in the study woreda (Dereje ,2017). The result is consistent with the world bank study report on Ethiopia which is projected that climate change reduce yields of crop production by 33% (World Bank ,2007).

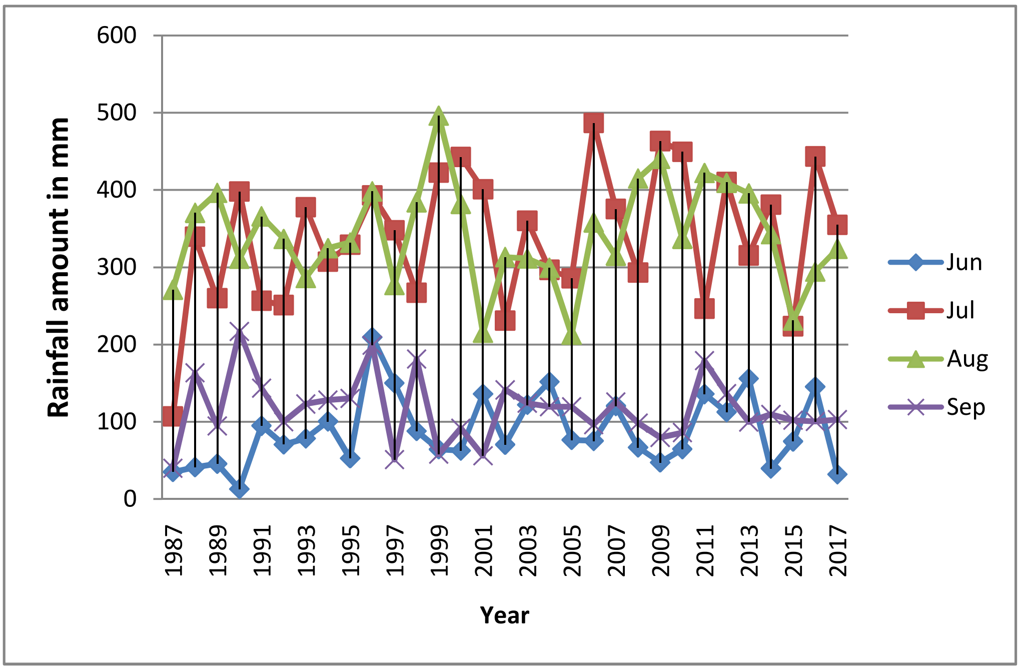


Figure 11. Rainy season (Jun-Sep) precipitation amount of Gerar Jarso woreda (source : computed from NMA meteorological data)

As it is observed from the focus group discussion, key informant interviews and reports of the Gerar Jarso woreda agricultural and natural resource office , there is organic relationship between the number of households covered by the safety net programme and the magnitude of rainfall shortage and variability in each consecutive years.

4.3 Community Perception on Climate Variability And Change

In the assessment of farmers perception over a 30 year period, respondents perceived decline in rainfall, increase in temperature and concomitant declines in tree cover and crop production. Such observations are important, but do require further triangulation with available meteorological records. As it is indicated in Figure 12, farmers' perception (knowledge) of past climatic events is in agreement with 30 years of temperature records than precipitation. But during the FGD farmers reported the existence rainfall variability in their assessment of the last three decades. This perception is consistent with climatic records (meteorological data) of Fiche station. From the perception scale measurement, farmers also perceived the decline of soil fertility which leads to yield reduction.

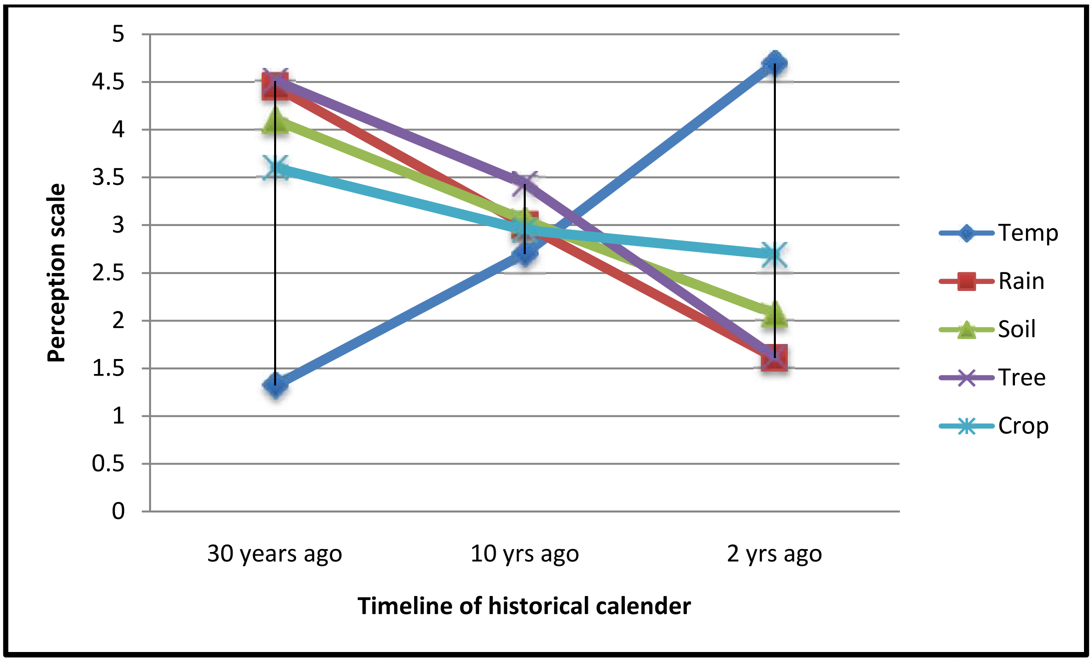


Figure 12. Community perception on rainfall, temperature, soil fertility status, tree cover, and crop production. (Source: Computed from field data) (Scale of 1-to-5, where 1 is very low, 2 is low, 3 is no change, 4 is high and 5 is very high.)

The presence of a significant number of food insecure households in the Woreda (Table 9) is a real indication of crop production decline. When smallholder farmers are asked whether they worry about food security or not, almost 44% of the respondents were worried about food security. The yield decline due to rainfall and temperature changes was also verified by FGD results. During the FGD, discussants attributed the decline in crop production, decrease in rainfall and rising temperatures which leads to deforestation. Farmers' perception and knowledge on climate change and variability are important to understand and assess strategies of climate change impacts.

Table 9. Food security status of the study area

Do you worry about food security ?	Frequency	%	Cumulative %
No	113	56.2	56.2
Yes	88	43.8	100.0
Total	201	100.0	

(Source : computed from field data)

4.4 Farmers' View Towards Climate Smart Agricultural Practices

As it is indicated in Figure 13, the study revealed that 92% of smallholder farmers are positively perceived as CSA practices can overcome several environmental problems such as soil degradation , water resource deterioration, climate change and variability. Survey results and FGD outcomes in all the study kebeles indicated that, most farmers were willing to adopt the CSA practices. Those who were willing to adopt the practices indicated that increasing yield and soil fertility improvement as the main driving force for their adoption demand. Such results indicate the importance of understanding of the need of the rural farmers and their perception before the implementation of CSA interventions. Such results are in line with other studies (Gwambene et al ,2015; Eric , 2012). The studies suggested the importance and needs for considering local community perceptions in planning for intervention. According to these studies, local communities have knowledge developed for a long time in their surroundings through experience and practices which are important in developing adaptation and mitigation strategies. Consideration of their knowledge and experience is important for up and out scaling and sustainability of the interventions.

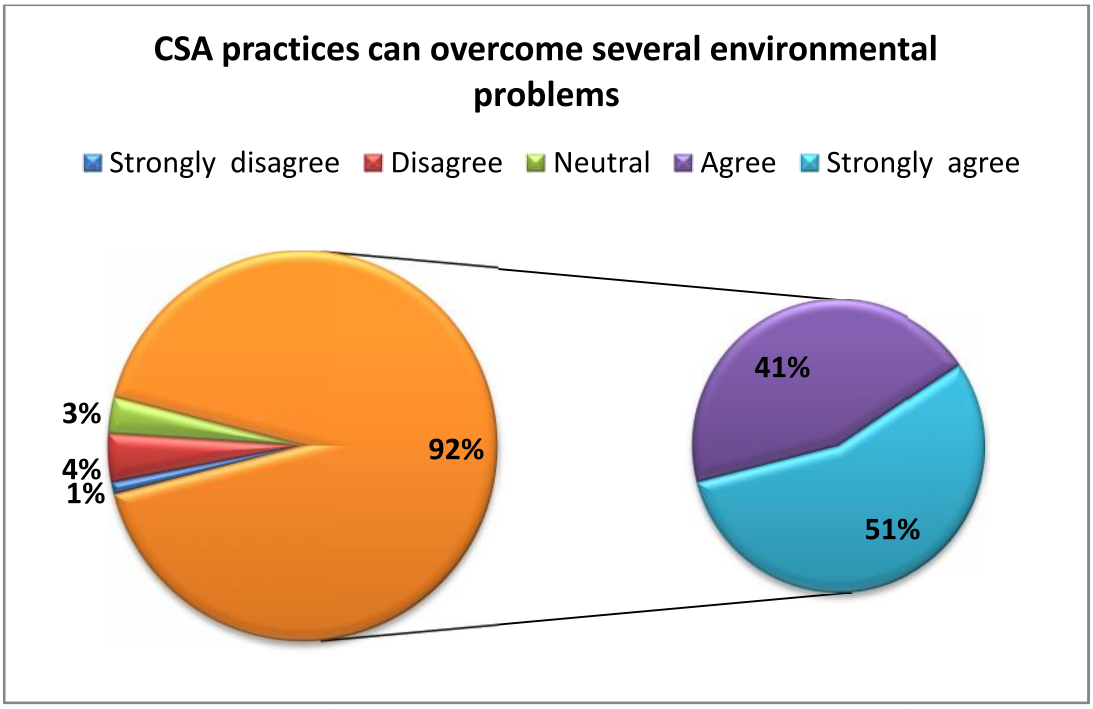


Figure 13. Perception results on CSA practices in Gerar Jarso Woreda (Source : computed from field data)

Environmental concern for the next generation and application of compost received the highest consideration among smallholder farmers (Table 10). Application of compost is perceived by farmers as the best soil management practice which improves soil fertility. The respondents perceived that natural resources should be protected both for the present use and for future generations even if it leads to farmers incurring cost in the short run. Cultivation of legume crops and crop diversification was ranked third and considered as one of the best soil erosion protection practices. The results are consistent with that of Erich (2012). Minimum tillage was ranked fourth as a practice that helps to reduce soil erosion disturbance and exposure. In the case of Ethiopia, land preparation is mainly carried out with a view of getting rid of weeds, but it also helps in breaking compacted soils and improves moisture infiltration. However, moisture infiltration is much better in soils that are less tilled but not compacted by the effect of overgrazing.

Contrary to Gwambene et al (2015) and Eric (2012), crop rotation was perceived being least compare to other soil and water management practices. Most of the time farmers prefer to plant high value crops continuously. Poor farmers do not incline to rotate by low market value crops. This is why *teff* is common in every harvesting season.

Table 10. Farmers' view towards climate smart agricultural practices

Statement	Mean	Std. Deviation	Rank
Natural resources must be protected for the next generations	4.66	.652	1
Soil fertility can be improved by application of compost	4.66	.476	2
Leguminous species and crop diversification can protect soil from erosion	4.55	.556	3
Minimum tillage reduces soil erosion, disturbance and exposure	4.53	.700	4
Growing multipurpose trees and shrubs in steeper slope land can reduce soil erosion and improve soil fertility	4.50	.657	5
I have to protect natural resources even if it	4.49	.530	6

will lead to incurring losses in the short run			
Mulching or Retaining crop residues reduce weed growth, reduce moisture loss and reduce erosion by water and wind	4.38	.726	7
By storing water farming operation can be done during the dry season	4.36	.808	8
Soil fertility can be improved by application of green manure	4.33	.810	9
Boundary planting and windbreaks can protect soil erosion and improve water retention of the soil	4.31	.725	10
Growing trees in association with crop production generate additional income and able to improve my livelihood	4.30	.923	11
Drought resistance crops are selected in low rain fall season	4.26	1.031	12
Terraces can improve the water retention capacity of the soil	4.23	.860	13
Slope stabilization improve the water availability in the soil	4.23	1.009	14
Intercropping can improve soil fertility	4.21	.962	15
Alley cropping provides nutrients specially nitrogen to the soil	4.20	.764	16
Crop rotation reduces soil degradation	4.04	.964	17

(Source : computed from field data)

4.5 Types And Characteristics of CSA Practices Carried Out by Smallholder Farmers

The study revealed that smallholder farmers have adopted various climate smart agricultural practices to overcome several environmental problems such as diminishing soil fertility, climate change and variability etc. The ultimate goal of adopting such practices is to enhance food security and improve household income. The most commonly practiced CSA practices in the study area are portrayed by Figure 16. That of all the CSA practices known, crop diversification received a high priority among rural farmers (71%). This was followed by other practices such as crop rotation (65.2%) and uses of drought resistance crops (55.2%). Irrigation received the lowest priority as 23 % of the respondents reported to have adopted it . As it is revealed from key informant interviews, utilizing crop diversity ensure food security, resilience to climate change and minimize the adverse effect of mono-cropping, especially the build-up of pests and diseases. Nowadays, crop pests and diseases were critical challenges for rural subsistence farming. Therefore, crop diversification by popularizing of new crops and crop varieties is acknowledged for sharing of the total risk of crop failure.

Figure 14. Terracing practice at *Wertu Kebele (Photo taken in*

Figure 15. Compost preparation at *Ginno Kebele (Photo taken in 24/4/2018)*

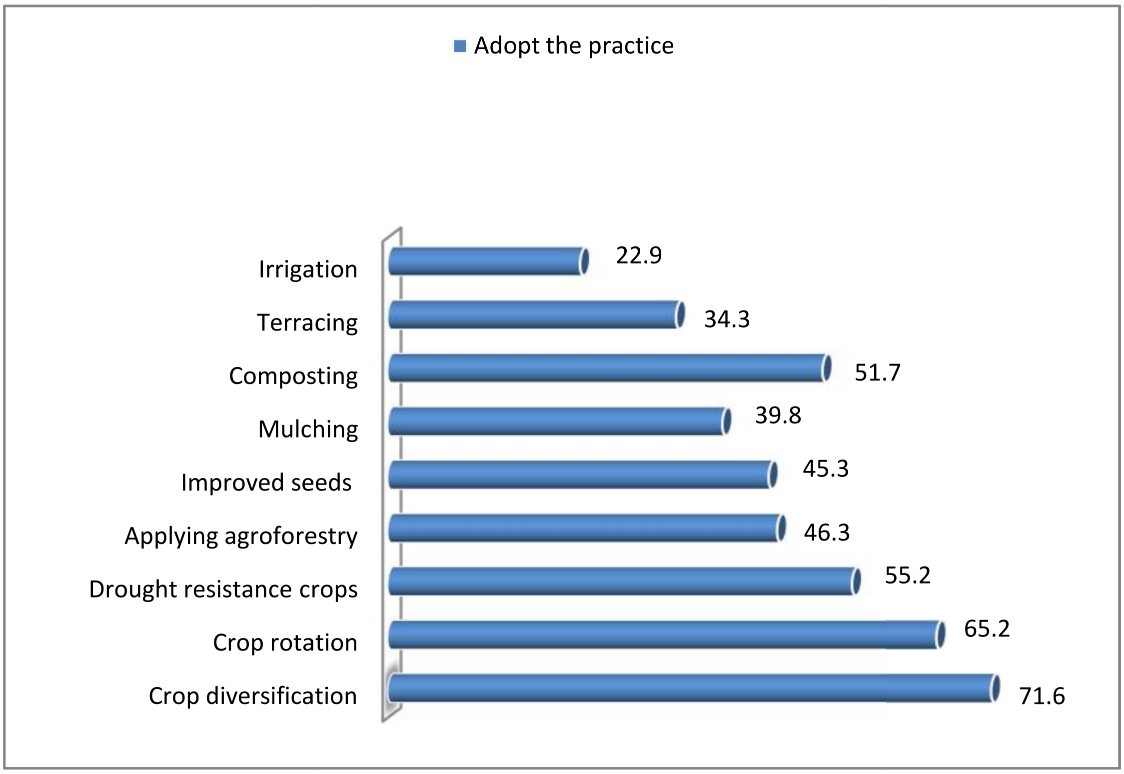


Figure 16. Percentage of CSA practices adopted by household farmers (computed from field data)

In general, compare to a high positive perception or willingness to adopt CSA practices with actual adoption status, farmers of the study area were by far low adopters (Figure 17). Majority of CSA practices conducted in the study area were practiced by less than half of the rural farmers. Adoption is a mental process that begins when a farmer learns of an innovation, and ends at the final adoption stage (Rogers, 2003). The behaviour process and effect of an agent depends on the intensity of its perception and attitude. But, positive perception or attitude alone is not sufficient for adoption decision. Other factors should be also considered. The low adoption status of climate smart agriculture was associated with socio-economic, bio-physical, cultural and institutional factors. Basing on key informant interviews and FGD, rural farmers have a number of constraints to adopt and expand appropriate and feasible climate-smart and climate-resilient agriculture practices. Shortage of water and lack of labour to prepare compost, lack of animal feed and fuel wood to apply mulching, lack of seedlings to promote agroforestry and lack of water, lack of access to credit and lack of training to adopt small scale irrigation are some of the prominent bottlenecks.

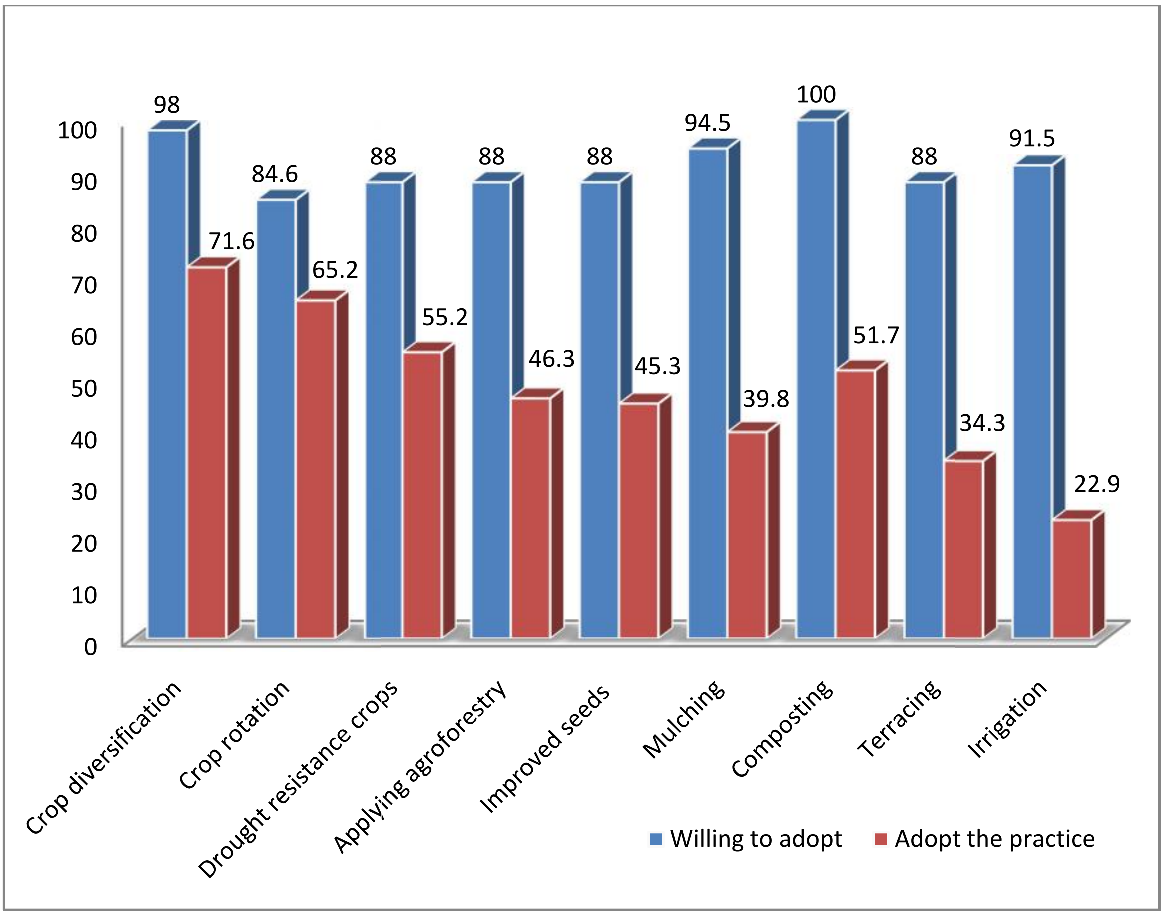


Figure 17. Willingness to adopt and adoption status of CSA practices (Source : computed from field data)

Figure 18. Boundary planting agroforestry practice at *Adisgie Kebele (Photo taken in 27/4/2018)*

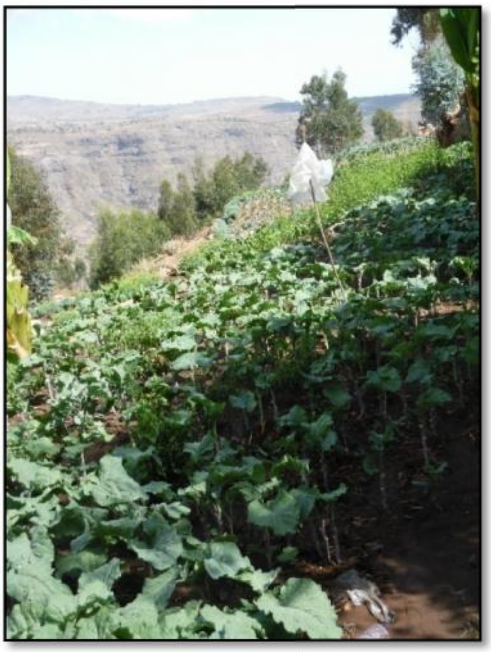


Figure 19. Small scale irrigation practice at *Adisgie Kebele. (photo taken in 27/4/2018)*

4.6 Determinants of Farmers' Adoption of Climate Smart Agricultural Practices

This section presents factors that affect farmers' decision to adopt three climate smart agricultural practices in Gerar Jarso woreda. The three regressed dependent variables are: composting , agroforestry and mulching (Table 11).

Table 11. Descriptive Statistics for the logistic regression model (n=201).

Variable	Mean	Std. Deviation
Adoption of compost	.52	.501
Adoption of agroforestry	.46	.500
Adoption of mulching	.40	.491
Age	47.36	12.086
Sex	.88	.325
Labour force proportion	58.34	22.045
Family size	5.43	1.751
Education	.43	.496

Number of parcel	2.87	.929
Farm size	2.04	.981
Home distance from farm plot	27.89	16.85
Degradation	.35	.478
Home market distance	85.77	29.66
Home main road distance	40.67	31.70
live stock number	3.18	3.83
Off farm income	.40	.492
Extension service	.79	.411
Training	.83	.380
Radio	.49	.501
Weather forecasting	.47	.500
Farmers' field days	.65	.479
Member of organization	.59	.493
Access to credit	.42	.494
Environmental regulation	.67	.473

(Source : computed from field data)

4.6.1 Logit model regression results of farmer's adoption of composting practice in Gerar Jarso woreda.

This section identified the most important hypothesized independent variables that influence farmers' decision to adopt composting in the study area. The dependent variable was either adopting or not adopting of composting. In this case, a farmer who carried out composting practice was considered to be "an adopter". In model diagnostics, the Hosmer and Lemeshow test is used to estimate the good-fit model, and if the p-value is above 0.05 (statistically non-significant) the estimated model has adequate fit, and if the p-value is below 0.05 (statistically significant) the estimated model does not adequately fit the data. In this research, the P-value was 0.983, and the model fit very well (Table 12). The rate of correct model prediction was up to 90.5%. From all sample farmers, the correctly predicted adopters and correctly predicted non adopters of the model were 90.4% and 90.7 %, respectively. In the logistic regression model summary, over all model evaluation (likelihood ratio), statistical tests of individual predictors (Wald statistics), goodness of-fit statistics (R^2) are presented. In standard regression, the co-efficient of determination (R^2) value gives an indication of how much variation in Y is explained by the model. This cannot be calculated for logistic regression but the model summary table showed the values for two pseudo R^2 (Cox & Snell R Square and Nagelkerke R Square (pseudo R^2)) which try to measure something similar. In the estimated model, pseudo R^2 is 83.7%. It indicates that, of the total variation in the dependent variable, 83.7% was explained by the independent variables.

Out of 21 explanatory variables that were hypothesized to affect farmers' decision to practice composting or not, only 8 of them were found statistically significant (Table 12). These significant explanatory variables include : sex of the household head (DSEX), labour force proportion (LABOR), education level of the household head (DEDUC), average farm distance from home (FRMDIST), number of livestock (DLIVSTOK), extension service contact per year (DEXTSERV), access to weather forecasting (DWEATHER) and being member of rural organizations (DORGANZ). Number of farm plots ,average market distance from home, main road average distance from home , having radio and participation in farmers' field day were found to have positive effect on composting practicing but not statistically significant. On the other hand, age, family size, degradation, training , access to credit and knowledge on environmental regulation were negatively related with composting practicing but the relation was statistically insignificant.

Table 12. Determinants of compost adoption in Gerar Jarso woreda

Variables	**Estimated coefficient (B)**	**Std.error (S.E.)**	**Wald Statistics (Wald)**	**p-value**	**Odds ratio of adopting Exp(B)**
DAGE	-.015	.026	.341	.559	.985
DSEX**	5.156	2.045	6.360	.012	173.487
LABOR**	.041	.017	5.666	.017	1.041
FAMSIZE	-.125	.173	.525	.469	.882
DEDUC*	3.401	.815	17.405	.000	29.994
PLOTNR	.103	.430	.057	.811	1.109
FRMSIZE	-.047	.376	.016	.901	.954
FRMDIST**	-.048	.023	4.459	.035	.953
DDEGRAD	-1.183	.863	1.880	.170	.306

MKTDIST	.019	.015	1.676	.195	1.019
RDDIST	.001	.013	.006	.936	1.001
DLIVSTOK*	1.260	.268	22.046	.000	3.526
DOFFARM	.797	.772	1.065	.302	2.218
DEXTSERV***	1.653	.995	2.758	.097	5.222
DTRAING	-.566	1.290	.192	.661	.568
DRADIO	1.354	.863	2.458	.117	3.871
DWEATHER*	-3.596	1.169	9.455	.002	.027
DFIELDAY	.404	.901	.201	.654	1.498
DORGANZ*	2.622	.920	8.130	.004	13.763
DCREDIET	-.870	.792	1.208	.272	.419
DENVREGU	-.503	.763	.435	.510	.605
Constant	-11.449	3.414	11.245	.001	.000
Number of obs.	201				
Hosmer and Lemeshow Test	.983				
-2 Log likelihood	79.920				
Cox & Snell R Square	.627				
Nagelkerke R^2	.837				
Prediction statistic	90.5				

* Significance level at $p < 0.01$, ** Significance level at $p < 0.05$, *** Significance level at $p < 0.1$

(source : Model estimation output)

4.6.2 Logit model regression results of farmer's adoption of agroforestry practices in Gerar Jarso woreda.

This section identified the most important hypothesized independent variables that influence farmers' decision to adopt agroforestry practices in the study area. The dependent variable was either adopting or not adopting of agroforestry. In this case, a farmer who carried out agroforestry practice was considered to be "an adopter". In model diagnostics, the Hosmer and Lemeshow test is used to estimate the good-fit model, and if the p-value is above 0.05 (statistically non-significant) the estimated model has adequate fit, and if the p-value is below

0.05 (statistically significant) the estimated model does not adequately fit the data. In this research, the P-value was .740, and the model fit very well (Table 13). The rate of correct model prediction was up to 79.6%. From all sample farmers, the correctly predicted adopters and correctly predicted non adopters of the model were 76.3% and 82.4 %, respectively. In the logistic regression model summary, over all model evaluation (likelihood ratio), statistical tests of individual predictors (Wald statistics), goodness of-fit statistics (R^2) are presented. In standard regression, the co-efficient of determination (R^2) value gives an indication of how much variation in Y is explained by the model. This cannot be calculated for logistic regression but the model summary table showed the values for two pseudo R^2 (Cox & Snell R Square and Nagelkerke R Square (pseudo R^2)) which try to measure something similar. In the estimated model, pseudo R^2 is 55%. It indicates that, of the total variation in the dependent variable, 55% was explained by the independent variables.

Out of 20 explanatory variables that were hypothesized to affect farmers' decision to practice agroforestry or not, only 7 of them were found statistically significant (Table 13). These significant explanatory variables include : sex of the household head (DSEX), labour force proportion (LABOR), , average farm distance from home (FRMDIST), average market distance from home (MKTDIST), access to weather forecasting (DWEATHER), participation in farmers' field day (DFIELDAY) and knowledge on environmental regulation (DENVREGU) . Family size, education level ,number of farm plots , farm size, degradation, , off-farm income , extension service, main road average distance from home , having radio and training were found to have positive effect on agroforestry practicing but not statistically significant. On the other hand, age, member of organization and access to credit were negatively related with agroforestry practicing but the relation was statistically insignificant.

Table 13. Determinants of agroforestry adoption in Gerar Jarso woreda.

variables	Estimated coefficient (B)	Std. error (S.E.)	Wald Statistics (Wald)	p-value	Odds ratio of adopting Exp(B)
DAGE	-.002	.018	.008	.927	.998
DSEX*	2.163	.834	6.729	.009	8.699
LABOR*	.037	.011	11.911	.001	1.038
FAMSIZE	.100	.116	.747	.387	1.105
DEDUC	.418	.450	.863	.353	1.519

PLOTNR	.114	.258	.195	.659	1.120
FRMSIZE	.080	.264	.093	.761	1.084
FRMDIST**	-.030	.015	4.320	.038	.970
DDEGRAD	.019	.460	.002	.967	1.019
MKTDIST*	.026	.009	9.453	.002	1.027
RDDIST	.007	.007	.935	.334	1.007
DOFFARM	.414	.442	.880	.348	1.514
DEXTSERV	.220	.531	.172	.679	1.246
DTRAING	.552	.621	.790	.374	1.736
DRADIO	.813	.531	2.344	.126	2.254
DWEATHER**	-1.254	.627	4.006	.045	.285
DFIELDAY**	1.388	.583	5.675	.017	4.009
DORGANZ	-.071	.535	.017	.895	.932
DCREDIET	-.231	.459	.254	.614	.793
DENVREGU*	1.517	.495	9.387	.002	4.558
Constant	-9.586	2.121	20.432	.000	.000
Number of obs.	201				
Hosmer and Lemeshow Test	.740				
-2 Log likelihood	170.800				
Cox & Snell R Square	.412				
Nagelkerke R^2	.550				
Prediction statistic	79.6				

* Significance level at $p < 0.01$, ** Significance level at $p < 0.05$ (source : Model estimation output)

4.6.3 Logit model regression results of farmer's adoption of mulching practices in Gerar Jarso woreda.

This section identified the most important hypothesized independent variables that influence farmers' decision to adopt mulching in the study area. The dependent variable was either adopting or not adopting of mulching. In this case, a farmer who carried out mulching practice was considered to be "an adopter". In model diagnostics, the Hosmer and Lemeshow test is used to estimate the good-fit model, and if the p-value is above 0.05 (statistically non-significant) the estimated model has adequate fit, and if the p-value is below 0.05 (statistically significant) the estimated model does not adequately fit the data. In this research, the P-value was 0.808, and the model fit very well (Table 14). The rate of correct model prediction was up to 80.6 %. From all sample farmers, the correctly predicted adopters and correctly predicted non adopters of the model were 73.8% and 85.1 %, respectively. In the logistic regression model summary, over all model evaluation (likelihood ratio), statistical tests of individual predictors (Wald statistics), goodness of-fit statistics (R^2) are presented. In standard regression, the co-efficient of determination (R^2) value gives an indication of how much variation in Y is explained by the model. This cannot be calculated for logistic regression but the model summary table showed the values for two pseudo R^2 (Cox & Snell R Square and Nagelkerke R Square (pseudo R^2)) which try to measure something similar. In the estimated model, pseudo R^2 is 53.7%. It indicates that, of the total variation in the dependent variable, 53.7% was explained by the independent variables.

Out of 21 explanatory variables that were hypothesized to affect farmers' decision to practice mulching or not, only 6 of them were found statistically significant (Table 14). These significant explanatory variables include : Labour force proportion (LABOR), family size (FAMSIZE), farm size (FRMSIZE), average farm distance from home (FRMDIST), Off-farm income (DOFFARM) and having radio (DRADIO) . Sex of the household head, average market distance from home, degradation, training , number of livestock, being member of rural organizations, and participation in farmers' field day were found to have positive effect on mulching practicing but not statistically significant. On the other hand, age, education level of the household head , extension service contact per year , number of farm plots, access to weather forecasting , access to credit, main road average distance from home and knowledge on environmental regulation were negatively related with mulching practicing but the relation was statistically insignificant.

Table 14. Determinants of mulching adoption in Gerar Jarso woreda.

Variables	Estimated coefficient (B)	Std. error (S.E.)	Wald Statistics (Wald)	p-value	Odds ratio of adopting Exp(B)
DAGE	-.029	.018	2.554	.110	.972
DSEX	1.059	.873	1.471	.225	2.883
LABOR*	.050	.011	19.840	.000	1.052
FAMSIZE**	.287	.120	5.746	.017	1.332
DEDUC	-.643	.473	1.844	.174	.526

PLOTNR	-.215	.263	.666	.415	.807
FRMSIZE***	.499	.273	3.338	.068	1.647
FRMDIST*	-.046	.017	7.628	.006	.955
DDEGRAD	.167	.465	.129	.720	1.181
MKTDIST	.009	.008	1.146	.284	1.009
RDDIST	-.006	.007	.747	.387	.994
DOFFARM*	1.204	.450	7.149	.008	3.333
DEXTSERV	-.491	.550	.799	.371	.612
DTRAING	.237	.625	.144	.704	1.268
DRADIO**	-1.268	.566	5.011	.025	.282
DWEATHER	-.747	.614	1.479	.224	.474
DFIELDAY	.564	.586	.926	.336	1.757
DORGANZ	.726	.530	1.878	.171	2.068
DCREDIET	-.777	.473	2.702	.100	.460
DENVREGU	-.136	.500	.074	.786	.873
DLIVSTOK	.052	.057	.824	.364	1.053
Constant	-4.136	1.890	4.787	.029	.016
Number of obs.	201				
Hosmer and Lemeshow Test	.808				
-2 Log likelihood	168.540				
Cox & Snell R Square	.397				
Nagelkerke R^2	.537				
Prediction statistic	80.6				

* Significance level at $p < 0.01$, ** Significance level at $p < 0.05$, *** Significance level at $p < 0.1$

(source : Model estimation output)

4.6.4 Demographic factors and adoption of climate smart agricultural practices

The most statistically influential demographic factors that hypothesized as independent variables to affect the probability of adopting composting, agroforestry and mulching practices are: sex, labour force proportion, family size and education level.

Sex of the household heads is positively correlated with the adoption of composting and agroforestry practices at statistically significance level (B=5.156 ; p- value= .012) (Table 12) and (B= 2.163 ; p- value = .009) respectively (Table 13). The Wald statistics 6.36 for composting and 6.729 for agroforestry also indicated that sex has a strong association with the adoption of the practices . Moreover, the coefficients and odds ratio of these explanatory variable were by far larger than other variables. This showed that, being male-headed farm household will intensify the probability of adopting compost and agroforestry on farmlands than being female-headed. The odds ratio of logistic regression showed that male household heads are more likely adopt composting by the factor of 173.487 and agroforestry by 8.699 than female headed households. This appears to be reasonable in that most female-headed households did not plough their own farm plots . Most of the women households employed different mechanisms of getting returns from their farm lands. Renting farmlands either in the form of money or crop was common in the study area. This is because female headed households lack labour to cultivate and conserve their farmlands. In addition, females are involved in taking care of their children and other related tasks at home. Moreover, all female household heads are widowed or divorced and don't have support other than their children. Their socio-economic marginality compare to males in different parameters therefore, retards them back to adopt the practices which demands time, energy ,capital and social networks. The result of this study is consistent with (Daniel and Mulugeta , 2017; Germew, 2016 and Abay et al, 2016) which were conducted in rural Ethiopia.

Labour force proportion (the percentage of household members age between 15 to 64) had a positive correlation at statistically significance level with insignificant impact (composting: B=0.041 , p-value =0.017 ; agroforestry : B= 0.037 ; p-value =0.001and mulching : B=0.050 ; p-value =0.000) on the adoption of the practices. The results were affirmed by the wald statistics of 5.666 , 11.911 and 19.840 for composting, agroforestry and mulching respectively (Table 12,13 and 14). As it is predicted in the model, if a farm household has more active labour force in the family, the odds of adopting composting practices increased 1.041 times, agroforestry practices increased 1.038 times and mulching practices increased 1.052 times than a family endowed with a high age dependency ratio. This explains that a farm household family consists higher active work age members could affect the probability of CSA adoption positively. Practically, the practices are labour intensive. The quantitative result was verified by transect walking how the practices demand much labour. Unexpectedly, however, active labour force endowments is not significant in affecting the probability of using compost unlike the case in other studies (Mengistu and Bauer , 2011). The reason for this is not clear, it might imply that the availability of adult labour in the family was less important for the adoption decision.

The logit model predicted that education level of farm household head variable influences composting practicing positively and significantly at 1% significance level (Table 12). This showed that relatively better educated farmers are engaged in the adoption of composting practices. The odds ratio of the variable indicates that all other factors being the same, farmers whose education level is elementary and above practiced composting 29.994 times more likely than non-educated (illiterate) farmers. The result revealed that better exposure to education increases farmers' better understanding of the benefits and constraints of adopting the practice. A positive impact of education on technology acquisition is generally expected as it enhances farmer's ability to acquire and analyze new ideas, and provides specific or general skills that contribute to farm productivity (Workneh, 2015).

Similar to the finding of this study, (Daniel and Muluget , 2017; Workneh, 2015; Eric ,2012,) reported that education gives farmers the ability to perceive, interpret and respond to new information much faster than farmers with lower education level (non-educated). Thus, those household heads with better education level have a higher probability of adopting best practices.

In the case of mulching, the regressed binary logistic model revealed that an increase in the family size of the household leads to a rise in the likelihood of adopting mulching practices on the farmlands. The study result showed that, when the family size increased by one number, the likelihood of mulching adoption increased 1.332 times (Table 14). Labour is main concern in the decision to adopt labour intensive technologies. Hence, large family size is a source of labour for adopting agricultural practices in rural Ethiopia.

4.6.5 Physical factors and adoption of climate smart agricultural practices

Among the farm physical factors employed in the logistic regression model, average farm distance from home is captured as an influential predictor of composting, agroforestry and mulching practices. The models revealed that farm plot distance from home had a negative and insignificant impact on farmers' adoption decision (composting : B = -0.048, p-value = 0.035; agroforestry: B = -0.030; p-value = 0.038 and mulching: B= -0.46 ; p- value = 0.006) (Table). The negative sign shows that as the farm plot distance increases, the probability to adopt CSA practices decreases (Table 13 and 14). The result is consistent with prior prediction. In the study area the average time taken to reach farm plot is almost 28 minutes

(Table 11). This showed that transporting CSA practices materials to farm plots highly discouraged farmers to adopt the practices. In the study area, compost has been preparing around the homestead especially in the house garden area for the purpose of follow up the bio chemical process and security . The odds ratio indicated that being other variables constant, a one minute increase in distance of farmland from a farmer's home decreases adoption of composting by a factor of 0.953, agroforestry by a factor of 0.970 and mulching by a factor of 0.955 (Table 14). This revealed that greater distance of a plot from homestead may have discouraged farmers from giving the necessary care and maintenance for the plot. Because less time and energy are consumed for maintaining the soil fertility of near farmlands than far farmlands. In line with this, Daniel and Mulugeta (2017); Robera (2013) ; Eric (2012); Mengistu and Bauer (2011): Kessler (2006) and Birhanu and Swinton (2003) also found that, distant farmlands discouraged adoption of any soil and water conservation practices. It is more tedious to carry compost manure and mulching materials from the homestead to the farm and this may require employing more labour and capital. This leads to raise cost of production which hinders farmers' to adopt the practices.

In the case of agroforestry , contrary to the stated hypothesis, market distance from farmers' homestead had a positive impact on adoption at 1% significance level (Table 13). The reason for this might be farmers' adopt agroforestry type other than high value trees which couldn't be marketable and generate income. But study conducted by Germew (2016) at Mecha district of western Gojam, in agreement with the stated hypothesis showed that, as the distance of the farm household from the proximal market areas increased by one percent (one minute), the probability of agroforestry adoption would be declined by 21% units. This is because of the demand for fuel wood and wood construction materials might induce the proximate farm-households to adopt agroforestry on their farmlands.

4.6.6 Economic factors and adoption of climate smart agricultural practices

The number of livestock holding by farm household head had a significantly positive impact on adoption of composting practices, which supports the hypotheses of the model. This explanatory variable is highly influential at 1% significance level with estimated coefficient and odds ratio of adopting 1.260 and 3.526 respectively (Table 12). The odds ratio result from the estimated model depicted that, as the number of livestock increases by one tropical livestock unit (having one extra ox or two donkeys or ten sheep etc.) , adoption of compost increases by a factor of 3.526. Since, livestock are important providers of manure for compost preparation, as farmers' hold more livestock; by far they are encouraged to prepare and apply compost in their farmlands. Also, livestock holding in rural Ethiopia in general and in the study area in particular is considered as indicator of income level and hence wealth status of the households. It shows farmers financial ability to buy even commercial composts for their farmlands. On the other hand, some of the livestock type like donkey and horse are still important means of transports for goods and human being in the study area. So, a farm household having a number of livestock is not challenged in applying compost to their farmlands which are even takes more than 28 minutes from homestead . So, a large number of livestock presences in rural family minimize time, energy and costs of practicing composting. The result is agreed with that of Workneh (2015) and Mengistu and Bauer (2011) .

Farm income other than agricultural activities (Off-farm income) is the most influential factor that affects farmers' decision to adopt mulching. The result of the regressed model depicted that off-farm income has a positive correlation at statistically significant level (B = 1.204; p-value =0 .008) with the adoption of mulching practices (Table 14). The odds ratio of the binary logistic regression result revealed that household heads who are engaged in off-farm activity adopt mulching practices 3.333 times greater than those who are not engaged in the off-farm activity. Because income from off-farm activity increases the financial capacity of farmers which in turn encourages investment in soil and water conservation practices.

Contrary to this, Daniel and Mulugeta (2017) reported that off-farm activity is correlated negatively at statistically significant level with the adoption of soil and water conservation practices. They argued that, there is labor competition between off- farm activity and soil and water conservation practices which restrain farmers from involving in implementing and maintaining conservation practices on their farmlands.

As expected, the other economic factor, farm size was found to be positively associated with mulching adoption (B= 0.499 ; p- value = 0.068). From the predicted model result (Table 14) , it was found that, if farm plot increases by one hectare, adoption of mulching increases by a factor of 1.647. The positive coefficient of the variable implies that farmers with larger farm size are more likely to adopt mulching compared with those with small farm size. Farmers with large farm size can afford to devote part of their plots (sometimes the less productive parts) to try out high yield giving technologies, and this may influence adoption decision.

In line with this (Robera , 2013 ; Rafael ,2005) argued that, relatively larger farm size had higher risk of adopting improved agricultural practices. This can be attributed to the fact that fertility enhancement occupies part of the scarce productive land and, therefore, farmers with larger farm size can afford it compared to those with relatively lower farm size.

4.6.7 Institutional factors and adoption of climate smart agricultural practices

Not surprisingly, farm household heads who have access to agricultural extension service and who are members of rural organizations like rural cooperatives and other forms of associations are more likely adopt composting. Access to extension service more than three times per one cropping season had a positive correlation at statistically significance level (B = 1.653; p-value = 0.097) with the adoption of composting . The other institutional factor, being member of rural organizations, also positively and significantly affects the likelihood of using compost at B = 2.622 and p-value = 0.004 (Table 12). The odds ratio of extension service was 5.222; if extension service increased by 1 service contact, the probability of adopting compost increases 5.222 times. Similarly, the odds ratio of member of organizations was 13.763, denoted that farmers being member of organizations were 13.763 times more likely to adopt composting practices than that of being non members.

This showed that extension service and rural organizations are important sources of information and knowledge for rural farmers. Based upon the innovation diffusion theory, farmers who have contacts to extension services tend to be more progressive and receptive to new innovation. However, some farmers may strategically delay adoption of a new practice until they build confidence through watching and learning from fellow farmers. In FGD and key informant interview contacts, farmers said that they got also information about compost preparation and application from other farmers. Nowadays, farm organizations like rural cooperatives, Youth associations , women associations and rural kebele administrations are best places to acquire trainings and experience sharing opportunities. Even, indigenous institutions like *Idir* and *Maheber* are still played an important role for agricultural technologies information exchanges. These indicate formal and non-formal institutions are key for farmer-to-farmer information exchange for technology adoption.

Rural organizations expose farmers to a wide range of ideas and sometimes give farmers the opportunity to have better access to information on new innovations. Group membership also enables farmers to have a collective bargaining power when selling their product as well as purchasing farm inputs (Eric, 2012).

The findings about the influence of extension service and rural organizations on compost adoption in this research are consistent with those of Daniel and Mulugeta (2017) and Workneh (2015) who analyzed the adoption of soil and water conservation techniques and composting in south wollo zone of Amhara region and Beseku district of Oromia region repectively. Also, Wang et al (2016) ; Eric (2012) and Somada et al (2002) reported similar findings on composting technology adoption in China, Kenya and Burkina Faso respectively.

Farmers' field day participation influences agroforestry practicing positively and significantly. This imply the variable is one of the motivating factors for practicing agroforestry. The coefficient and odds ratio of this variable were 1.388 and 4.009 respectively (Table 13). Keeping other factors constant, when farm household heads get an opportunity of extra one day participation in farmers' field day, they could be 4.009 times more likely to practice agroforestry. Research results by Gitonga and Mukoya (2016) showed that, adoption of agroforestry practices can be strengthened by promoting regular farmers-to-farmers dialogue. From the practice it is observed that farmers are the prime agents of change in their respective communities. One of rural institutional set ups that create exposure to farmers-to-farmers dialogue on their success stories is farmers' field day. It is a practical experience sharing arrangement among farmers' to promote adoption of high beneficial agricultural practices like agroforestry. In most cases rural farmers delay adoption of a new practice until they build confidence through watching and learning from fellow farmers. Therefore, the best time to build confidence and learn by watching is farmers' field day.

The other institutional factor, knowledge on environmental regulation had positively correlated with the adoption of agroforestry practices at statistically significance level (B= 1.517 ; p- value = .002). The Wald statistics (9.387) also indicated that the variable has a strong association with the adoption of agroforestry practices (Table 13). If a farmer is knowledgeable on environmental regulations, the likelihood of adopting agroforestry practices increases 4.558 times. The results are consistent with that of Wang (2016).

When farmers' get some knowledge and highlights on Ethiopia's environmental regulations such as environmental policy of Ethiopia, agriculture sector programme of plan on adaptation to climate change and climate resilient green economy strategy, they could develop a better attitude towards eco friendly agricultural practices. The policies and regulations are mainly address the mechanisms how environmental degradation and climate change adverse impacts could be manageable. So, the issue of environment influences attitude of farmers' in the study area who are mainly living in degraded environment.

A study by Tanga and Amare (2016) reported that, farmers' awareness about land degradation and their attitude towards land management practices leads farmers' to have positive attitude towards land management practices including agroforestry.

Although from FGD and key informant interview, it is verified that, environmental regulation statements are boldly written on farmers land use certificate. The entitlement card enforces them to conserve their environment. However, some farmers even indicated that they had never heard of the environmental regulations, which indicates that the popularization of the regulations are not enough and that the laws also do not perform their role of advising, regulating and supervising.

Contrary to the stated hypothesis, information to weather forecasting had a negative and significant impact on compost adoption at 1% significance level and agroforestry adoption at 5% significance level (Table12 and13). The reason for this might be the absence of the timely available weather information and high probability of weather prediction accuracy. If so, the variable was less important for the adoption decision.

Radio is assumed to give information about climate smart agricultural practices to farmers and hence it is expected to affect adoption decision positively. However, Contrary to the stated hypothesis, radio had a negative and significant impact on mulching adoption at 5% significance level (Table 14). The reason for this might be the absence of sufficient and well organized radio programmes concerning farming activities that influence adoption decision of farmers.

4.7 Challenges to Invest on Climate Smart Agricultural Practices

Climate smart agricultural practices could be considered as investments for long term and short term returns. Investment is the present sacrifice for future benefit. Farmers' are regularly in position to decide whether or not to invest, and how to diverse among the options available. An individual farmers' might have to decide whether to apply or not crop diversification, crop rotation, small scale irrigation, agroforestry, composting, mulching , improved seeds etc. Under the heading of investment decision, economists have addressed the problem of how to rationally choose in such situations involving a trade-off between present and future. Farmers' investments in different CSA practices depend on the how quick the return from their investments is. In view of this, three elements are needed to determine farmers' investment decision. These include; capacity to invest, incentives to invest and external conditioners.

4.7.1 Capacity to invest on climate smart agricultural practices

Farmers' capacity to invest in CSA depends on farmers real assets such as landholding and livestock, labour availability, knowledge and experience , social capital , physical capital and financial capital.

Lack of financial capital is not allow about 24% of non-adopters to invest in composting practices (Figure 21). Financial capital consists of not only cash but also liquid assets such as livestock and crop sales that are used to finance CSA practices. Livestock, crop sales and off farm activities are the main sources of cash for Ethiopian farmers (Zenebe et al, 2015). If farmers generate income from these sources they could easily access inputs for the practices . Besides, they could also easily purchase the available CSA practices when needed. On the other hand lack of cash and liquid assets even drive farmers' to exchange CSA practices by cash rather than invest on their farmland. Figure 26, presents 33% of non adopters responded that shortage of money drives them to sell organic mulching materials rather than invest it on their farmland. Also 29% of mulching adopters presented that need of additional income to sell crop residual mulching materials which limited them to expand mulching practices (Figure 20).

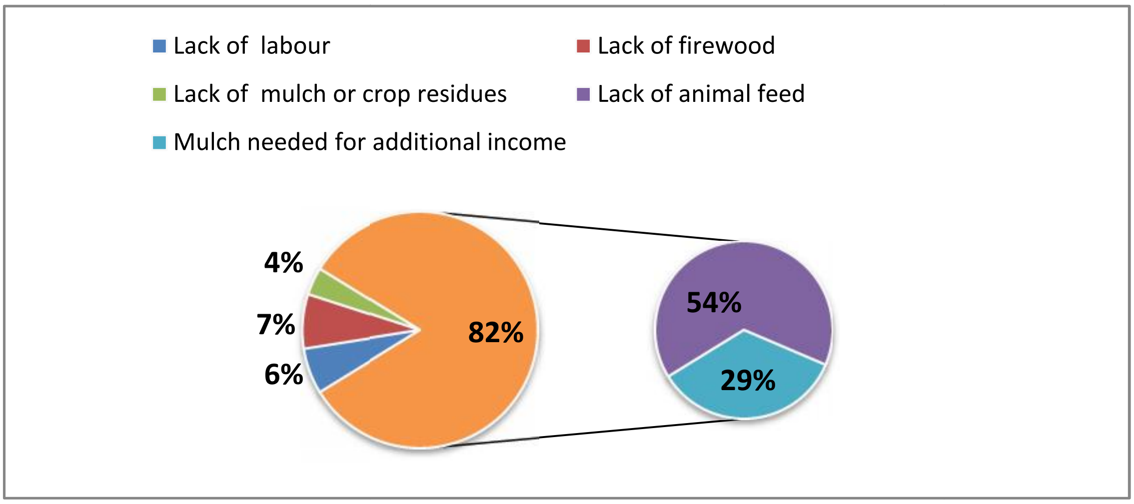


Figure 20. Limit to expand mulching (Source: computed from field data)

A research conducted by Dereje and Haymanot (2017), entitled as Poverty and income inequality in Girar Jarso District of Oromia Regional State, estimated that 45% of the district residents are poor. The figure is more than the regional and national averages (29.3 and 29.6% respectively). In such low economic status situation, money hunger is common to alleviate life challenges. So, crop sales and livestock rising may not be the only sources of income for the rural household.

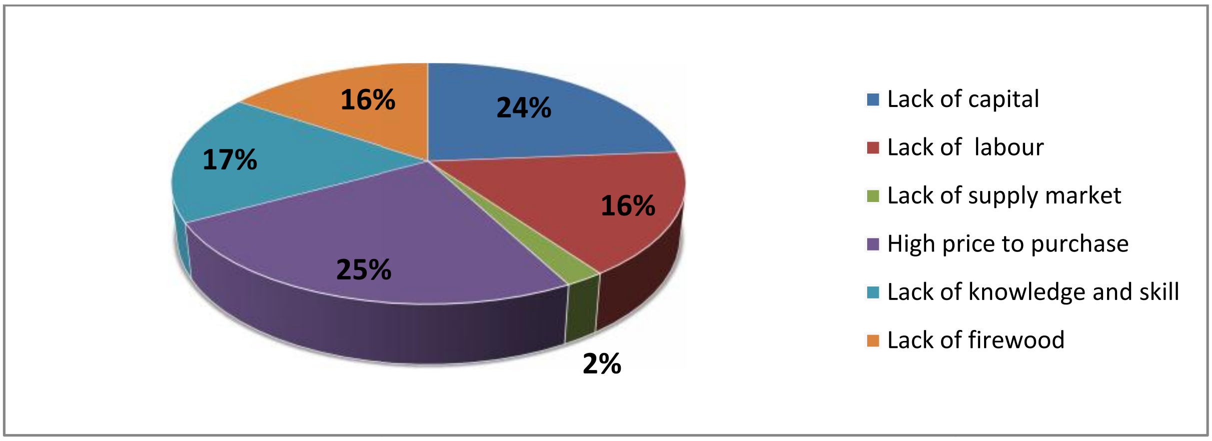
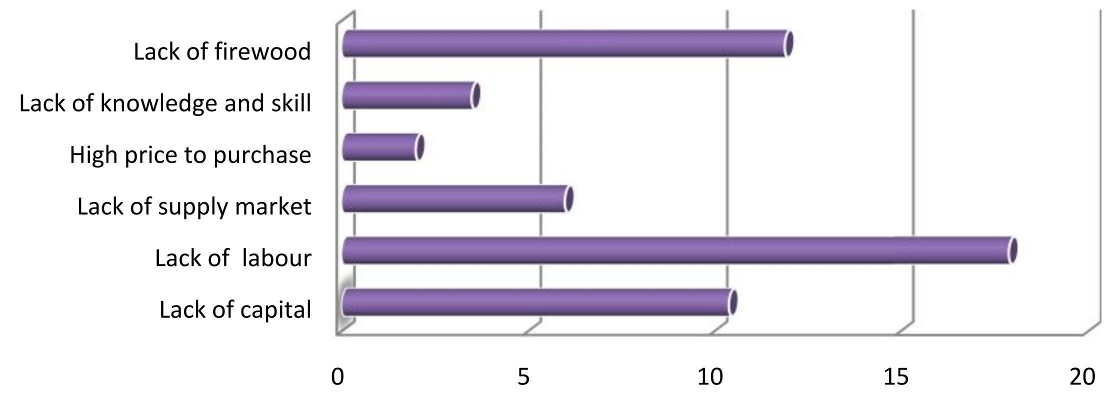


Figure 21. Challenge to invest on composting (Source: computed from field data)

As Figure 21 depicted ,16 % of compost non-adopters raised lack of labour as a constraint factor to invest composting practices. Similarly 17.9% and 25.8% of composting and agroforestry adopters respectively responded that lack of labour restrained them to expand the practices on their farm plots (Figure 22 and 25).



	Lack of capital	Lack of labour	Lack of supply market	High price to purchase	Lack of knowledge and skill	Lack of firewood
■ Limit to expand composting	10.4	17.9	6	2	3.5	11.9

Figure 22. Limit to expand composting (Source: computed from field data)

Labour availability in quantity and quality terms is critically important in CSA practices investment. The quantity aspect of labour is important when considering labour as an input used in labour intensive CSA practices such as construction of stone terrace, preparation and transportation of composting, agroforestry etc. The quality of labour which includes knowledge and technical skill are also important to the farmers' ability to make appropriate investment decisions (Zenebe et al, 2015). As shown in Figure 21, 17% of compost non adopters raised lack of sufficient knowledge and skill as influential factors.

Like the case in other studies (Workneh , 2015), lack of knowledge and skill to prepare compost is one of major hindering factors to adopt the practice in Gerar Jarso woreda. According to Workneh (2015), a research conducted at Beseku district of Oromia region, 50% of the constraint factors that drives rural farmers not to adopt composing practices is lack of knowledge and skill.

Since population pressure and severe land degradation minimizes productive farm size of rural families , 22% of agroforestry non-adopters raised shortage of land as a reason for not-adopting the practice (Figure 23). It implies farmers are calculating the opportunity cost of land use to apply agricultural technologies in their farmlands. Gwambene et al (2015) in their research conducted at southern highlands of Tanzania , revealed that farmers will not invest all their resources if they are not assured about the outcome of the technology or practice. Adoption of new technology and practices in most cases is affected by the perceived opportunity cost of land use. Landholding is the major source of wealth and livelihood in Ethiopia. The quantity and quality of land affect the types and intensity of investments which are technically feasible and profitable.

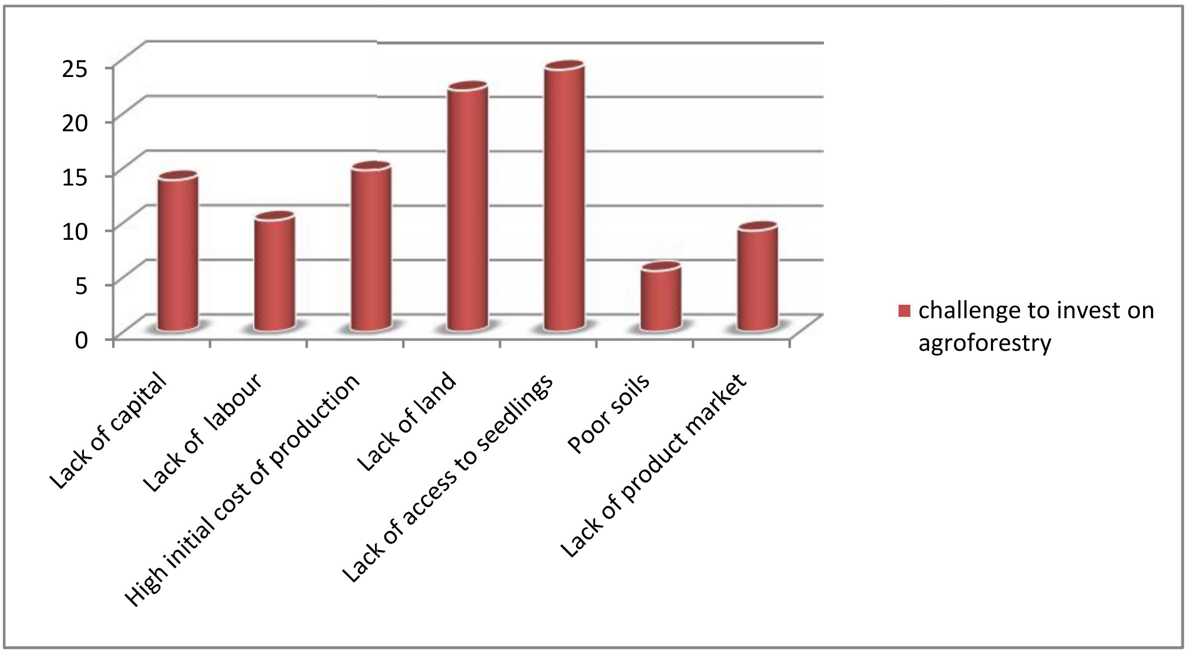


Figure 23. Challenge to invest on agroforestry (Source: computed from field data

4.7.2 Incentives to invest in CSA practices

About 25% of the non-adopters of compost indicated that high price to purchase compost was highly hindering them from practicing composting (Figure 21). From field observation and FGD it is verified that, the compost market is Oligopoly type of market which is dominated by few suppliers. The nature of such market gives price setting power to the sellers by different arrangements. So, farmers are obliged to accept higher selling price.

The factors that affect farmers' incentives to invest in CSA practices are related to those conditions that affect the net or relative return of investments and riskiness of investment in CSA. Most farmers in Ethiopia are sensitive to net or relative return to their labour or financial investments in land (Zenebe et al, 2015;). If the costs of CSA practices exceed the short –term and the long term benefits, farmers have no incentive to adopt them. Net returns of a given investment depend on the yields and input requirements per unit of output and the prices of inputs and outputs.

Another important factor affecting farmers' incentives to invest in CSA practices is risk. Climatic risk (e.g. rainfall) and risk of losing their property (e.g. land tenure) farmers can affect investments in land. In this study 66% of farmers reported that they are insecure to use their farm land throughout their life (Figure 24) .The importance of secure and transferable land rights has long been identified as a key element to bring about higher levels of long term investment (Tanga and Amare ,2016; Zenebe et al, 2015;)

As it is common in Ethiopia, the land belongs to the state in the study area , However few years ago usufruct right is allowed for farmers. According to an assessment of land tenure systems and investments in farmlands, farmers preferred freehold land tenure systems for CSA practices adoption implying the positive influence of tenure security. A study conducted on adoption of agroforestry practices at Fogera district of northern Ethiopia revealed that security of land tenure influenced agroforestry adoption positively and significantly (Tanga and Amare ,2016). When Farmers believe that no one can take their land from their hand, they invest conservation practices intensively and extensively to improve land productivity.

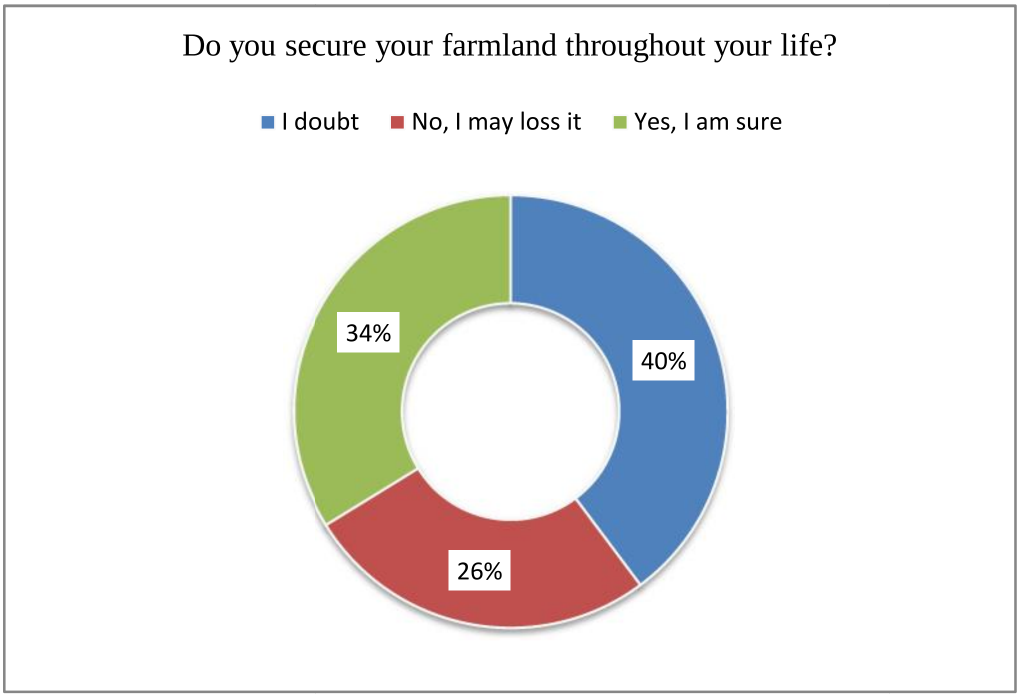


Figure 24. Farmers' view on the security of land tenure (Source: computed from field data)

4.7.3 External conditioners to invest in CSA practices

External factors affect farmers' investments in CSA practices indirectly by influencing their capacities to invest in CSA and the incentives of their investments. These external factors include institutional support (provision of trainings, extension services, agricultural inputs and technologies), policies (e.g. land tenure) and access to infrastructure (e.g. road and market).

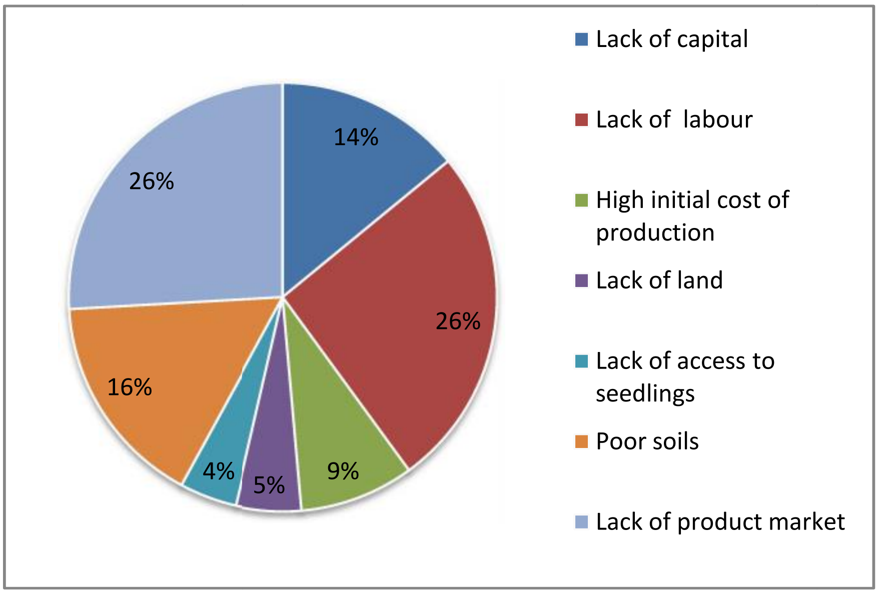


Figure 25. Limit to expand agroforestry (Source: computed from field data)

As shown in Figure25, 26% of agroforestry adopters reported that lack of product market discouraged them to expand their agroforestry investment. In the study area, majority of farmers walk more than two hours to access road and market. These infrastructure challenges raise the transaction costs of products, raw materials and access to various information to get reasonable financial rewards from their investment.

One of the most important bottlenecks to adopt and expand mulching practices in the study area is lack of animal feed. 28% and 54% of mulching adopters and non-adopters respectively agreed with this proposition (Figure 20 and 26). In recent years, it is observed that due to climate variability and change animal feed shortage become chronic in most part of Ethiopia. Its impact is clearly seen especially to invest on mulching. There is a clear trade-off between livestock feed and organic mulching materials. Almost all organic mulching materials such as crop residuals, dry grasses, straws, dry leaves, grass clipping, etc. are animal feed types especially in the dry season. So, farmers due to their relative return perception, inclined to use the mulch for animal feed or income generation rather than invest it as conservation practices.

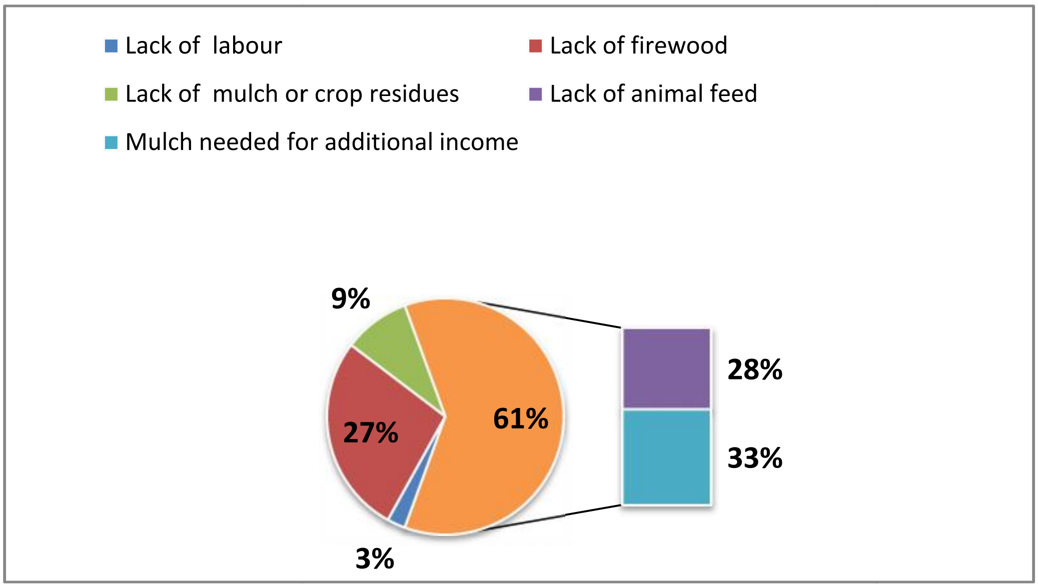


Figure 26. Challenge to invest on mulching (Source: computed from field data)

In assessing why smallholder farmers were unable to invest on agroforestry practices, about 24% of the non-adopters indicated lack of access to seedlings as a major constraint factor (Figure 23). From direct observation and FGD it is acquired that, farmers in the kola *kebeles* are chronically affected in having seedlings.

Figure 26 presents, 27% of mulching non-adopters raised shortage of firewood to apply mulching. It means, rural household families are high consumers of mulching materials such as: bark, wood chips, straws, dry leaves, etc as a source of fuel to cook their food.

In FGD and key informant interviews, shortage of water is also considered as key challenge not to adopt composting. Even to expand the practice significantly, water shortage is also considered as a bottleneck by adopters.

Lack of labour for CSA non- adopters is insignificant constraint factor compare to other factors (Figure 21, 23 and 26). When farmers are communicated in FGD and key informant interviews, they argued that if the demand of the prominent factors such as firewood , animal feed, access to seedlings and water supply are fulfilled , lack of labour in the family is compensated by using different indigenous social capitals such as: *wenfel*, *debo/ jigi* , *senebete / mahiber*.

Therefore, improving animal feed availability, access to seedlings, alternative fuel energy sources and water supply infrastructures are some of the critical tasks that should be managed by formal and informal institutions in the study woreda. The tasks also need policy support and suitable strategies designed by higher governmental institutions.

Figure 27. *Adisge kebele* farmers carrying mulching materials to sell at Fiche market (photo taken in 27/4/2018)

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The general objective of this study was to assess determinants and challenges of climate smart agricultural practices adoption in Gerar Jarso woreda of Oromia regional state. From the meteorological data and farmers' perception it is observed that the average annual temperature is characterized by an increasing trend. Besides, rainfall variability is observed in the study area. These changes intensify the impacts of droughts, and could particularly reduce the amount of productive crop land and exacerbate food insecurity among rural farmers. To tackle this climate smart agriculture (CSA) is rapidly gaining traction as a possible response to the challenge.

In this study three climate smart agricultural practices are examined by demographic, physical, socio-economic and institutional aspects of rural farmers.

The study revealed that sex of household heads, education level of household heads, number of livestock holding, access to extension services and being member of rural organizations affect adoption of composting positively and significantly. Also, farm distance affect composting practices negatively.

The probability to apply agroforestry is positively and significantly associated with sex of household heads, farmers' field day participation and knowledge on environmental regulation. Besides farm distance affect the likelihood of agroforestry application negatively.

The model result also demonstrated that off-farm income, farm size, the presence of active labour force and family size affect adoption of mulching practices positively. Besides, average farm distance from homestead affect the probability of mulching adoption negatively.

The study identified that when farmers' capacity to invest and incentives to invest is limited and insufficient enabling conditions exist smallholder farmers could not invest and/or expand CSA practices investment in short and long terms.

Adoption of climate smart agricultural practices that maintain or improve soil fertility have a positive effect on agricultural productivity. Therefore, the issue of CSA practices has to receive due attention in an effort to ensure sustainability of the rural livelihood system and food security goal of the country in the face of climate change. In this regard commitment of every stakeholder is required in fostering the use of the practices through supporting those who already implemented and increasing awareness among non-users to encourage them to adopt the practices.

Therefore, the findings of the promising demographic, socio-economic, and institutional factors should be given to capitalize by the Woreda Agriculture and natural resource development office and other concerned bodies to enhance farmers' adoption potentials of the study area. Moreover, before expanding CSA practices in other areas of Ethiopia, addressing the implementing obstacles by establishing enabling local environments through enhancing farmers' implementing capacities and incentives to implement is crucial.

Finally, given the limitations of this study , there are some implications that do deserve further research. These include:

- The necessity to consider the broader aspect of environment beyond agricultural land conservation including livestock production, conservation of water, wetlands, forest, and biodiversity through the lens of CSA;
- The need to have time series information for assessing the dynamic nature of adoption on the basis of the variables considered in this study ;
- The need to employ other models such as Tobit model for assessing adoption intensity among rural farmers; and
- The need to have wider coverage (geographically) and diverse coverage (beyond the three CSA practices) of adoption study.

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Appendix I. Household Questionnaire

Questionnaire Identification

- Woreda .... Kebele ……….……… Location………………..…
- Agro - ecology ☐ Dega ☐ Weyina dega ☐ Kolla
- Name of enumerator……………………………… Mobile No …………………
- Date ………………… Starting time …………… Ending time …………

I. Farmers' Background Information

1.1 Marital status *(Please tick where appropriate)*

☐ 1. Single ☐ 2. Divorced (separated)
☐ 3. Married ☐ 4. Widowed 5. If any other specify ………………

1.1 Household members (including the head) Demographic Characteristics

NO	Name	sex	Age	Relation to the head	Years of schooling	Main responsibility in the house
1						
2						
3						
4						
5						
6						
7						

1.3 What is the occupation of the household head?

☐ 1. Crop farming
☐ 2. Livestock Farming
☐ 3. Mixed farming , if mixed the dominant one is ……………………
4. Others (specify)………………..

1.4. How many years have you been in the current farming system? ………………….

2 Farmer's Perception

2.1 What is your observation/perception on climate variability , soil fertility status , tree cover and crop production around your environment in this year than : *(Using the following Key: 1 very low , 2 low, 3 no change , 4 high and 5 Very high put (√) in the box provided)*

Indicators	30 years ago					10 years ago					2 years ago				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Temperature															
Rain															
Soil fertility															
Tree cover															
Crop production															

2.2 What is your perception on expected effect of the following climate smart agricultural practices on your farm? (Use the following Key*: 1= strongly disagree; 2= Disagree; 3=Neutral / Undecided; 4= Agree; 5= strongly agree*and put (√) in the box provided *)*

Indicators	Statement	Perception rate				
		1	2	3	4	5
Natural resource conservation	i. Natural resources must be protected for the next generations					
	ii. I have to protect natural resources even if it will lead to incurring losses in the short run					
Soil management practices	i. Minimum tillage reduces soil erosion, disturbance and exposure					
	ii. Crop rotation reduces soil degradation					
	iii. Leguminous species and diversification of crops can protect soil from erosion					
	iv. Mulching or Retaining crop residues reduce weed growth, reduce moisture loss and reduce erosion by water and wind					
	v. Soil fertility can be improved by application of green manure					
	vi. Soil fertility can be improved by application of compost					
Agroforestry	i.growing trees in association with crop production generate additional income and able to improve my livelihood?					
	ii. intercropping can improve soil fertility					
	iii. boundary planting and windbreaks can protect soil erosion and improve water retention of the soil					
	iv. growing multipurpose trees and shrubs in steeper slope land can reduce soil erosion and improve soil fertility					
	v. alley cropping provides nutrients specially nitrogen to the soil					
Water management practices	i. terraces can improve the water retention capacity of the soil					
	ii. slope stabilization improve the water availability in the soil					
	iii. drought resistance crops (improved seeds) are selected in low rain fall season					
	iv. by storing water (irrigation) farming operation can be done during the dry season					

3 Physical Factors *(Please tick where appropriate)*

3.1 Farm Land Nature And Size

3.1.1 Total number of parcels ……………. Size …………. *Timad* (to mean '*Oolchaa sangaa'* in *Affan oromo*)

Type of parcel	Size in *timad*	Distance from the house (in minutes)	Land Quality (fertile, Moderately fertile degraded , severely degraded,)	Slope (plain , medium, sloppy)	Types of soil or/and water conservation practices applied	The land ownership type (ownership by title, rent or other)
Parcel 1						
Parcel 2						
Parcel 3						
Parcel 4						

3.2 Average house distance from the proxy market (in Min.) ……………. Minute

3.3 Average house distance from the main road (in Min.) ……………. Minute

4 Economic Factors

4.1 Do you posses an irrigated agriculture ? ☐ 1=Yes ☐ 0=No

4.2 If yes (for 4.1) , what is the size of the irrigated land in timad ? ………………

4.3 Currently how many of the following livestock do you have? (NB: Quantities registered will be converted to Tropical Livestock unit)

cows	Oxen	Bull	Calf	Heifer	Goat	Sheep	horse	Mule	donkey	poultry

4.4 Crop production and inputs used by household

NO	Crop type	Land size in Timad	2010 production in quintal	Type of seed used (local, improved)	Fertilizers in Kg per hactar
1.	Teff				
2.	Barley				
3.	wheat				
4.	Maize				
5.	Chickpea				
6.	Lentil				
7.	Pea				
8.	Faba bean				
9.	Potato				
10.	Onion				
11.	Garlic				
12.	Other				

4.5 Do you worry about food security ?

☐ 1=Yes ☐ 0=No

4.6 Off-Farm Income

4.6.1 Apart from farm income, do you receive income from other sources?

☐ 1=Yes ☐ 0=No

4.6.2 If yes, please indicate the other sources of income

Type of earning (income)	Average annual income (in birr)
Salary	
Transfer earnings from relatives (including remittance)	
Value of gifts received	
Income from Land rented out	
Daily Labourer	
Other incomes (specify) ………………..	

5 Institutional Factors

5.1 Extension Services

5.1.1 Has any household member receive extension service in the last 12 months?

☐ 1= Yes ☐ 0 = No

5.1.2 If yes (for 5.1.1), how many times do you usually meet with extension agents per cropping year ………………….

5.1.3 On what topics you get support from extension service?

………………………….. , ………………………….. , ……………………………….. , ………………………….. , ………………………….. , …………………………….. ,

5.1.4 Have you got extension service in the following Climate smart agricultural practices ? put (√) in the box provided.

Climate smart agricultural practices	Yes	No
Mulching		
Compost application		
Agroforestry practices		

5.1.5 Which institution provides you the extension service ? put (√) in the box provided.

Extension service provider	
1. Government (by extension workers-DA)	
2. private extension providers	
3. NGOs/development agencies	
4. other farmers	
5. others (specify) ……………………..	

5.2 Land Ownership

5.2.1 For whom do you think farm land belongs for natural conservation practices? put (√) in the box provided.

Government	My own	I am not sure

5.2.2 Do you expect that you will use the land throughout your life time? put (√) in the box provided.

I doubt	No, I may loss it	Yes, I am sure

5.2.3 Do you think land ownership title motivate farmers to adopt water management , soil management and agroforestry practices ?

☐ 1= Yes ☐ 0 = No

5.3 Training

5.3.1 Have you ever attended a training that improve your farm operation?

☐ 1= Yes ☐ 0 = No

5.3.2 If yes in (5.3.1), then complete the table below .

Training tiltles *(See codes below)*	Number of times	Training organizers *(See codes below)*

Codes for training title: 1 = compost use; 2= inorganic fertilizer usage; 3= building of terraces *4= mulching ; 5= water storage; 6= formulated fertilizer usage; 7= improved seed application; 8=* agroforestry practices ; 9= *other (specify) ……………………*.

Codes for training organizers: *1=Government extension Workers; 2=Farmers; 3=NGOs/development agencies ; 4=others (Specify)……………………*

5.3.3 So, how did you feel about the importance of the training? put (√) in the box provided.

Unimportant at all	A little bit good	I don't know	Very important

5.4 Information Access

5.4.1 Do you have radio?

☐ 1= Yes ☐ 0 = No

5.4.2 Do you think radio provides you an information on water management, soil management and agroforestry practices ? put (√) in the box provided *)*

1=strongly disagree	*2= Disagree*	*3=Neutral /Undecided*	*4= Agree*	*5= strongly agree*

5.4.3 Do you have regular access to weather forecasting information ?

☐ 1= Yes ☐ 0 = No

5.4.4 Do you usually participate in farmers' field days

☐ 1= Yes ☐ 0 = No

5.5 Organization

5.5.1 Are you a member of youth or women or farmers cooperative association ?

☐ 1= Yes ☐ 0 = No

5.5.2 Do you think being member of peasant association, capacitate farmers to improve their mulching , compost application and agroforestry practices adoption ?

☐ 1= Yes ☐ 0 = No

5.6 Credit Access

5.6.1 Did you have an opportunity to access credit?

☐ 1= Yes ☐ 0 = No

5.6.2 If yes in (5.5.1), fill the table below:

Credit source *(See codes below)*	Granted? 1=Yes 0=No	Credit type 1=Money 0=In kind	What was the purpose of credit? *(See codes below)*	If not granted, give reasons *(See codes below)*

Source codes: 1= Commercial bank, 2= private bank, 3=Cooperative, 4, microfinance 5= Local money lender. 6= others (specify) …………………………………………

Purpose of credit codes: 1=school fees, 2= business capital, 3= household consumption, 4=farm inputs (fertilizers and improved seeds), 5= livestock, 6= medication, 7=other (specify) …………………………….

Not granted reasons codes: 1= lack of collateral, 2= risk averseness, 3=lack of enough savings, 4=defaulted previously, 5= other (specify) ………………………

5.7 Environmental Regulation

5.7.1 Have you an information on the existence of environmental regulation ?

☐ 1= Yes ☐ 0 = No

5.7.2 Is the environmental regulation enforce you to apply water management, soil management and agroforestry practices ?

☐ 1= Yes ☐ 0 = No

6 Farm Operations

6.1 Do you practice the following farm activities ?

NO	Activity	Yes	No
1	Use crop diversification / Farming varieties of crops/		
2	Alterations in cropping patterns and rotations		
3	Use drought resistance crops		
4	Use soil and water conservation practices (Terracing) significantly		
5	Inclined to non farming activities		

6	Use storage water		
7	Applying agroforestry (Planting trees)		
8	Use of high irrigation water		
9	Use sufficient amount of fertilizer		
10	Use improved seeds sufficiently		
11	Use of BBM technology		

6.2 Climate Smart Agricultural Practices

6.2.1 Do you practice mulching?

☐ 1= Yes ☐ 0 = No

6.2.2 If yes in (6.2.1), what attracted you to practice mulching?

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

6.2.3 If yes, which factor is highly limit the expansion of your mulching practices?

☐ 1 Lack of capital ☐ 2 Lack of mulch or crop residues
☐ 3 Lack of labour ☐ 4 lack of firewood
☐ 5 Lack of animal feed (fodder) ☐ 6 lack of building material
7 Others (specify)……………………

6.2.4 If no in (6.2.1), which one is the most challenge for not adopting mulching practices?

☐ 1 Need of additional income ☐ 2 Lack of mulch or crop residues
☐ 3 Lack of labour ☐ 4 lack of firewood
☐ 5 Lack of animal feed (fodder) ☐ 6 lack of building material

7 Others (specify)……………………

6.2.5 Do you practice compost in appropriate management and composition ?

☐ 1 Yes ☐ 0 No

6.2.6 If yes in (6.2.5), what attracted you to practice compost?

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

6.2.7 If yes, which factor is highly limit the expansion of your compost practices?

☐ 1 Lack of capital ☐ 2 Lack of labour
☐ 3 Lack of supply market ☐ 4 high price to purchase
☐ 5 Lack of knowledge and skill ☐ 6 Lack of firewood
7 Others (specify)……………………

6.2.8 If no in (6.2.5), which one is the most challenge for not adopting compost practices?

☐ 1 Lack of capital ☐ 2 Lack of labour
☐ 3 Lack of supply market ☐ 4 high price to purchase
☐ 5 Lack of knowledge and skill ☐ 6 Lack of firewood
7 Others (specify)……………………

6.2.9 Do you adopt agroforestry practices on your farm land?

☐ 1= Yes ☐ 0 = No

6.2.10 If yes in (6.2.9), what attracted you to adopt agroforestry practices?

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

6.2.11 If yes in (6.2.9), Which of the following agroforestry techniques do you practice?

☐ 1 Intercropping ☐ 2 windbreaks

☐ 3 farm boundary planting ☐ 4 alley cropping

☐ 5 growing multipurpose trees and shrubs in steeper land structure

☐ 6 Growing high value trees (Jatropha, eucalyptus . . .)

7 Others (Specify) ……………………………

6.2.12 From the list above which is/are the main agroforestry technique/s on your farm?

6.2.13 If yes, which factor is highly limit the expansion of your agroforestry practices?

☐ 1 Lack of capital ☐ 2 High initial cost of production

☐ 3 Lack of land ☐ 4 Lack of access to seedlings

☐ 5 Poor soils ☐ 6 Lack of product market

☐ 7 Lack of labour 8 Others (specify)……………………

6.2.14 If no in (6.2.9), which one is the most challenge for not adopting agroforestry practices?

☐ 1 Lack of capital ☐ 2 High initial cost of production

☐ 3 Lack of land ☐ 4 Lack of access to seedlings

☐ 5 Poor soils ☐ 6 Lack of product market

☐ 7 Lack of labour 8 Others (specify)……………………

Appendix II

Checklist for Field Observation

1. Environment

1. Relief (plain, plateau, mountain, steep slopes)

2. Land-use and land cover

3. Soil aspects

4. Water bodies

2. socio- culture

1. Population settlement patterns

2. Religion

3. Culture, value, traditions

4. Social relations neighbourhood, network, reciprocity

3. Economy/Sources of livelihood/ and Infrastructure

1. Main source of livelihood: mixed farming, non-farm activities

2. Crop types: dominant in terms of area cultivated and size of harvest during *meher* and *belg* seasons, source of staple food

3. Livestock: type, size, raising practices

4. Situations of social and economic infrastructure: transport (road), marketing, extension services, sources of water supply, schools

Appendix III Challenges to invest on climate smart agricultural practices

No	Challenges to Invest	Composting		Agroforestry		Mulching	
		Frequency	Valid %	Frequency	Valid %	Frequency	Valid %
1	Lack of capital	23	23.7	15	13.9		
2	Lack of labour	16	16.5	11	10.2	3	**2.5**
3	Lack of supply market	2	2.1				
4	High price to purchase	24	24.7				
5	Lack of knowledge and skill	17	17.5				
6	Lack of firewood	15	15.5			33	**27.3**
7	Lack of mulch or crop residues					11	**9.1**
8	Lack of animal feed					34	**28.1**
9	Mulch needed for additional income					40	**33.1**
10	High initial cost of production			16	14.8		
11	Lack of land			24	22.2		
12	Lack of access to seedlings			26	24.1		
13	Poor soils			6	5.6		
14	Lack of product market			10	9.3		
	Valid total	97	100.0	108	100.0	121	**100.0**
	Missing system	104		93		80	
	Total	201		201		201	

(Source: computed from field data)

Appendix IV Limitation factors to expand climate smart agricultural practices

No	Limitation to expand investment	Composting		Agroforestry		Mulching	
		Frequency	Valid %	Frequency	Valid %	Frequency	Valid %
1	Lack of capital	21	10.4	13	14.0		
2	Lack of labour	36	17.9	24	25.8	5	6.3
3	Lack of supply market	12	6.0				
4	High price to purchase	4	2.0				
5	Lack of knowledge and skill	7	3.5				
6	Lack of firewood	24	11.9			6	7.5
7	Lack of mulch or crop residues					3	3.8
8	Lack of animal feed					43	53.8
9	Mulch needed for additional income					23	28.7
10	High initial cost of production			8	8.6		
11	Lack of land			5.4	5		
12	Lack of access to seedlings			4	4.3		
13	Poor soils			15	16.1		
14	Lack of product market			24	25.8		
	Valid total	104	100	93	100	80	100
	Missing system	97		108		121	
	Total	201		201		201	

(Source: computed from field data)