ADOPTION OF CLIMATE SMART AGRICULTURAL PRACTICES AND THEIR EFFECTIVENESS IN CROP- LIVESTOCK MIXED FARMING SYSTEM: THE CASE OF DIGALU-TIJO DISTRICT, ARSI ZONE, OROMIA REGIONAL STATE, ETHIOPIA

M.Sc. THESIS

AMAN HUSSEIN ADEM

HAWASSA UNIVERSITY

WONDOGENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, WONDO GENET, ETHIOPIA

OCTOBER, 2019

ADOPTION OF CLIMATE SMART AGRICULTURAL PRACTICES AND THEIR EFFECTIVENESS IN CROP-LIVESTOCK MIXED FARMING SYSTEM: THE CASE OF DIGALU-TIJO DISTRICT, ARSI ZONE, OROMIA REGIONAL STATE, ETHIOPIA

AMAN HUSSEIN ADEM

MSC THESIS SUBMITTED TO THE

DEPARTMENT OF AGROFORESTRY, SCHOOL OF GRADUATE STUDIES,
WONDO GENET COLLEGE FORESTRY AND NATURAL RESOURCES, HAWASSA UNIVERSITY, WONDO GENET, ETHIOPIA

IN PARTIAL FULFILLIMENT OF THE REQURIMENTS FOR THE

DEGREE OF

MASTER OF SCIENCE IN CLIMATE SMART AGRICULTURAL LANDSCAPE ASSESSMENT

OCTOBER, 2019

APPROVAL SHEET I

This is to certify that the thesis entitled ***"Adoption of Climate Smart Agricultural Practices and Their Effectiveness in Crop-Livestock Mixed Farming System: The Case of Digalu-Tijo District, Arsi Zone, Oromia Regional State, Ethiopia"*** submitted in partial fulfillment of the requirements for the degree of Master of science in Climate Smart Agricultural Landscape Assessment, the graduate program of The Department of Agroforestry and Soil Management has been carried out by **Aman Hussein** , under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence can hereby submit the thesis to the department.

Abdella Gure (PhD)	________________	_________________
Name of Major Advisor	Signature	Date
Beyene Teklu (PhD)	_________________	________________
Name of Co-advisor	Signature	Date
_________________________	_________________	_______________
Chair Man of Department	Signature	Date
____________________	_________________	______________
Postgraduate Coordinator	Signature	Date

EXAMINERS' APPROVAL SHEET II

We, the undersigned, members of the Board of examiners of the final open defence by Aman Hussein have read and evaluated his thesis entitled ***"Adoption of Climate Smart Agricultural Practices and Their Effectiveness in Crop-Livestock Mixed Farming System: The Case of Digalu-Tijo District, Arsi Zone, Oromia Regional State, Ethiopia"***, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfilment of the requirements for the Degree of Master of Science in Climate Smart Agricultural Landscape Assessment.

______________________	______________________	______________
Name of the Chairperson	Signature	Date
______________________	______________________	______________
Name of the Internal Examiner	Signature	Date
______________________	______________________	______________
Name of External Examiner	Signature	Date
______________________	______________________	______________
SGS Approval	Signature	Date

ACKNOWLEDGEMENTS

Above all, I thank the Almighty Allah for his protection and guidance since I was created till now. I'm grateful to my major advisor Dr. Abdella Gure for his commitment and assistance beginning with the elaboration of the thesis research title up to the end of this thesis. His skillful comments and feedback have contributed to the formulation of this thesis. My sincere thanks and appreciation are extended to my co-advisor, Dr. Beyene Teklu for his valuable comments and suggestions starting from the very beginning to the final stage of the work. Next, I would like to thank my organization (Digalu-Tijo District) for permitting and supporting me to attend this MSc program. I am also very much grateful to Hawassa University, Wondo Genet College of Forestry & Natural Resources for sponsoring my MSc study through the National Measuring, Reporting & Verification (MRV) Capacity Building towards Climate Resilient Development in Ethiopia, the project financially supported by the Royal Norwegian Government through its Embassy in Ethiopia.

I'm grateful to Mr. Kassim Dedefo, lecturer at Arsi University and wonderful friend, for providing me with a good working environment, during my thesis research, for his encouragement and moral support encouragement and moral support. I am also expressing deepest appreciations and special thanks to Abdusselam Tina, Girma Debela, Gena Shaku, Fikadu Habebe, Kedir Asha, Mohammed Amin and Wasen Tadesse, who helped me through the hardest of times to make it to where I am today. I would also like to thank all of the Key Informants, participants of the focus group discussion and household respondents from the study area who provided me with the necessary information.

Last but not least, my special thanks are due to my parents, brothers and sisters for their patience and love. Without their support and prayers, it would have been difficult to come this far.

Thank you all!

Contents

DECLARATION

I hereby declare that this thesis entitled *"Adoption of Climate Smart Agricultural Practices and Their Effectiveness in Crop-Livestock Mixed Farming System: The Case of Digalu-Tijo District, Arsi Zone, Oromia Regional State, Ethiopia"*, submitted in partial fulfilment of the requirements for MSc degree in Climate Smart Agricultural Landscape Assessment at Wondo Genet College of Forestry and Natural Resources, is my own work and not written by another author and also, has not been previously submitted to or accepted by any other university or institute for the award of any other degree.

Name: Aman Hussein Signature _________ Date______________

Place: Hawassa University, Wondo Genet College of Forestry and Natural Resources

LIST OF ABBREVIATIONS AND ACRONYMS

a.s.l	Above Sea Level
AEZ	Agro Ecological Zone
AHP	Analytic Hierarchy Process
^0C	Degree Celsius
CO_2	Carbon Dioxide
CSA	Climate Smart Agriculture
CSA	Central Statistical Authority
CSAPs	Climate Smart Agriculture Practices
CI	Consistency Index
CR	Consistency Ratio
CRGE	Climate Resilient Green Economy
EPA	Environmental Protection Authority
FAO	The 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
GO	Governmental Organization
HHH	Household Head
IIA	Independence of Irrelevant Alternatives
IPCC	Inter Governmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone

KAs	Kebeles Administration
KII	Key Informant Interview
MNL	Multinomial Logit
NAPA	National Adaptation Plan for Action
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
SNNP	Southern Nations, Nationalities and Peoples
SPSS	Statistical Package for social sciences
SSA	Sub Saharan Africa
SSI	Small Scale Irrigation
TLU	Total Livestock Unit
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

LIST OF TABLES AND FIGURES

List of tables

List of Figures

ABSTRACT

Title: Adoption of Climate Smart Agricultural Practices and Their Effectiveness in Crop-Livestock Mixed Farming System: The Case of Digalu-Tijo District, Arsi Zone, Oromia Regional State, Ethiopia.

Aman Hussein Adem ***Email***: *amexhussein@gmail.com*

Climate variability and change have been adversely affecting the livelihoods of smallholder farmers through their impact on crop and livestock production thereby affecting adaptive capacity of the smallholder farmers in developing countries. In order to minimize the impact of climate change/variability, various kinds of CSA practices and technological interventions were being made globally and locally in Ethiopia. The current study was conducted to identify CSA practices/technologies under implementation and to assess their adoption by smallholder farmers and their effectiveness in Digalu-Tijo district, of Arsi Zone of Oromia regional state. The study used multistage random sampling techniques. Primary data was collected from 150 randomly selected households using semi structured questionnaire. Additional qualitative data was collected through focus group discussion and key informant interview. The quantitative data was analyzed using both descriptive statistic and econometric analysis. The result of the study revealed that improved varieties, crop-livestock diversification, small scale irrigation, multipurpose tree planting and improved forage species were the five relatively more adopted CSA technologies in the study area. The results also revealed that adoption of improved varieties and small scale irrigation was significantly different between households in midland and highland agro-ecological zones, use of improved varieties being more preferred by those in midland agro-ecology (36% of respondents from midland against 19% of those from highland agroecology), while use of small scale irrigation was the most preferred option for those in highland agro-ecological zone (21% of respondents from midland against 3% of those from highland agroecology). Multinomial logit model revealed that agro-ecology, gender, family size, farm size, farming experience, education, annual income, livestock holding (TLU), access to climate information, access to extension and credit are factors that positively and significantly influence adoption of those CSA practices. Age of household head had an inverse relationship with the adoption and use of small-scale irrigation. The computed effectiveness of weight score estimates for income, food productivity and consumption were 0.57, 0.21 and 0.15, respectively. In terms of adaptation indicators, farm productivity, access to information, soil conservation skills and knowledge were estimated to have weight score of 0.20, 0.18, 0.14 and 0.13 respectively. it is concluded that CSA practices can contribute to increase productivity and enhance resilience of smallholder farmers. It is recommended that the level of adoption of CSA technologies particularly those that were indicated as least adopted still needs more efforts to work to make them more accessible to the farming communities.

***Key words**: Adaptation, Analytic hierarchy process, improved variety, multi-purpose tree planting, improved forage species, Likert scale, Multinomial logit model*

1. INTRODUCTION

1.1. Background

Nowadays, climate variability and change are among the major environmental challenge in the world. The negative implication of climate change on the agricultural sector is unequivocal, as its consequences affect the livelihoods of particularly smallholder farmers in the tropics (Elshamy *et al*., 2009; FAO, 2017). Given the expected rise in temperature, the negative effect on agriculture is also expected to be worsening. Extreme weather events, such as erratic rainfall, drought and heat stress are among the different signs of climate change (Elshamy *et al*., 2009).

In the countries like Ethiopia, where agriculture is entirely dependent on rainfall, an increase in temperature coupled with rainfall variability make Ethiopian agriculture the most susceptible to climate change (NMA, 2007; Word Bank, 2010; Tadesse Alemu and Alemayehu Mengistu. 2017). This rain fed and subsistence agriculture system, account about 34% of the country's GDP and 68% of population employment (World Bank, 2018). The sector is dominated by rain fed smallholder mixed crop-livestock farming, particularly those concentrated in the highlands (Kidane Georgis *et al*., 2010). However, such subsistence and rain fed agricultural production system has been under risk as a result of the complex environmental challenges, including land degradation as well as pest and insect infestations.

To address these challenges, agriculture in our country must undergo a major transformation in the coming decades in order to meet achieving food security, reducing poverty and responding to climate related risks without depletion of the natural resource base (FAO, 2010). Recently, climate-smart agriculture (CSA) 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. CSA is an approach to guide the management of agriculture with the aim of climate change (FAO 2018; Lipper and Zilberman, 2018). It is an umbrella term that includes many approaches built upon geographically specific solutions, and it is recognized as a potential means to support efforts from local to global for an agricultural system. The goal of CSA is to achieve sustainable agricultural development for food security through three pillars; production, adaptation and mitigation (Lipper *et al*. 2014; Thornton *et al*. ,2018). With its three pillars, CSA address sustainable increasing agricultural productivity and higher incomes, while adapting to climate change, maintaining healthy ecosystems that provide environmental services to farmers and reducing and/or removing greenhouse gas emissions where possible by enhancing GHG sequestrations.

In Ethiopia context, the government has launched on the climate resilient, green economy (CRGE) strategy to improve crop and livestock production by introducing CSA practices such as improved crop varieties and livestock breed, conservation agriculture, integrated watershed management, Agroforestry and improved fodder production and others for enhancing resilient and adaptive systems to climate change (FDRE, 2011). However, the adoption rate of CSA practices in Africa and Ethiopia is very low which account less than one million hectares due to a factor of biophysical, socioeconomic, demographic and policy challenges (Melaku Jirata, 2016; Suleman, 2017; Kiros Hadgu *et al*.,2019).

Empirical evidence supports the multi-faceted benefits of CSA at the global level (Branca *et al*., 2011). Recent studies showed that most of the climate smart practices have clear economic (Aryal *et al*., 2015; Khatri-Chhetriet *et al*., 2016) and climate change adaptation benefits (Sapkota et al., 2015; Aryal et al., 2016) for sustainable development goals. Selecting effective climate-smart interventions may contribute to achieving household demands, which include improved productivity, adaptation and mitigation, as well as meeting country's SDGs (Kiros Hadgu e*t al*.,2019). To implement and achieve the implications of CSA technologies, practices and policies, operational decision-making tools should be considered. The effectiveness of the introduced new practices to support farmers' in making decision to adopt CSA technologies, practices, and policies based on their locally specific resources, contexts, and agro ecology (Westermann *et al*., 2015; Thornton *et al*.,2018; Kiros Hadgu *et al*.,2019). However, information on how to identify, evaluate and verify target CSA innovations at the local level and understand the mechanisms to enable large scale adoption is fragmented (FAO, 2013).

The focus of this study is in Digalu -Tijo district of Oromia regional, state which is characterized as the highest agricultural production potential. A number of climate-smart practices such as improved varieties, small scale irrigation, tree planting, crop-livestock diversifications and improved forages are being practiced (Kassim Dedefo, 2018).

The study will attempt to assess the adoption of climate smart agriculture practice and their effectiveness in crop-livestock mixed farming system in Digalu- Tijo district.

1.2. Statement of the Problem

Currently climate variability is one of the major challenges for smallholder farmers in developing counties as a general and in Ethiopia particularly. Increased climatic variability, including changing rainfall patterns, repeated frequent floods and droughts, outbreaks of pests and diseases, associated with environmental degradation lead to greater instability in agricultural production and responsible for low productivity as well as limits options for coping with adverse weather conditions in smallholder farmers (Gornall *et al.* 2010; Paulos Asrat and Belay Simane, 2017).

With this stagnant growth, agricultural production, farmers try to full filling their demands by expansion of agricultural land through clearing of forest land without management wisely. Consequently, soil degradation has increasingly threatened the resilience of the ecosystems on which farmers have depended for a livelihood, which could also be worsened by prevailing social and economic challenges in the study area (Kassim Dedefo, 2018). Agricultural production is affected by climate-related shock in the area, which is usually manifested by land degradation problems as well as the occurrence of pest and insect infestations. The area is characterized by steep topography and gets a high rainfall amount ranging from 940-1,480mm. The steep topography combined with high rainfall made the area highly vulnerable to soil erosion and the spread of disease and pests. The primary result of soil erosion is a decrease in crop yield (Hurni et al. 2010; Temesgen Gashaw *et al*.,2014). In addition, localized weather shocks and incidence of livestock pests and disease outbreaks alter the feed intake, death rate, growth, reproduction, maintenance, and caused a shortage of fodder (Thornton *et al*., 2015; FAO, 2016b).

To make agriculture more productive and more resilient it requires a major shift in the way land, water, soil nutrients and genetic resources are managed. Thus, adopting climate-smart agriculture is thus crucial to ensure that these resources are used more efficiently in achieving future food security and climate change goals. Agricultural production systems that follow the general principles of the CSA are expected to be not only more productive and efficient, but also more resilient to short-, medium-, and long-term shocks and risks associated with climate change and variability (FAO, 2018).

Despite the potential benefits, the adoption of CSA practices is far below the expectation (Tewodros Beyene, 2018). A study conducted in Ethiopia at national level identified that the adoption rate of CSA practices is low due to lack of context specific and adequate research findings for the various agro-ecologies and heterogeneous crop-livestock farming system across the country (Melaku Jirata *et al*.,2016; Kiros Hadgu *et al*.,2019).

Various CSA interventions have been implemented for over a decade by government and No-government organizations in the study area. However, very limited studies have been carried out regarding the effectiveness of introduced CSA practices on food security and adaptation indicators in the area. As a result, there are few quantitative evidences related to the implications of CSA practices in the area which can undermine informed planning and decision making. A study conducted by Meron Tadesse (2018) in Tula Jana landscape, southern Ethiopia revealed CSA has positive implication both on crop and livestock productivity.

No evidence was gained regarding any research done on the topic in the area. Therefore, this study is conducted to fill the research gaps regarding adoption of CSA practices and their effectiveness in mixed crop-livestock farming system. In addition, this study aimed to identify adoption status, determining factors and effectiveness in adopting CSA practices.

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of the study was to assess the adoption of climate smart agricultural technologies by small holder farmers and to evaluate their effectiveness in the Digalu-Tijo district.

1.3.2 Specific Objectives

- ✓ To identify types of climate smart agricultural practices adopted by smallholder farmers and their level of adoption in the Digalu-Tijo district;
- ✓ To assess factors that influence adoption of climate smart agricultural technologies;
- ✓ To evaluate the effectiveness of the adopted CSA practices and technologies under a small holder farming system in the Digalu - Tijo district.

1.4. Research Questions

1. What are the CSA practices adopted by farmers in Digalu-Tijo district?

2.To what extent smallholder farmers are practicing CSA technologies?

3. What are the determinant factors that influence adoption of CSA practices in the study area?

4. Are the adopted CSA technologies effective in enhancing productivity with minimal burden on the environment?

1.5. Significance of the Study

This study is expected to provide relevant information regarding factors influencing adoption of CSA practices and a significant role in enhancing productivity and resilience for smallholder farmers. The results of study used to as a guideline document for further research in the study area and to the same climatic, socioeconomic and geographical areas. The end result is to enhance the effective, evidence-based decision-making process by all stakeholders and promote the adoption rate of CSA practice. Finally, the output of this study can be used by different users, such as researchers, extension workers, local community, environmentalist, NGOs, practitioners, academics and policy makers. In order to have appropriate measures to effectively and sustainable planning, implementing, monitoring, evaluation and upscaling in the context specific who needs to use it for further study in the country

1.6. Scope and Limitations of the Study

The study was carried out in Digalu-Tijo district, Arsi Zone of Oromia region. However, the scope of this study is limited to assessing the adoption of climate smart agricultural technologies and evaluating the effectiveness for mixed crop- livestock farming in Digalu-Tijo in Arsi Zone, Oromia Regional state, in four kebeles. The major limitation of this study was the considering of only six specific climate smart agricultural practices as adaptation option in the model and the sample size was also not large because of financial and time constraint.

2. LITERATURE REIEVEW

2.1. Key terms and definitions

Climate- is an average weather conditions over a longer period of time; the measurement of the mean and variability of related extents of certain variables (such as temperature, precipitation, wind and others) over a period of time, ranging from months to thousands or millions of years (UNCC, 2015; WMO, 2019)

Climate variability-is variations in the mean state and other statistical measures (deviations and statistics of extremes) of climate on temporal and spatial scale beyond that of individual weather events due to natural or anthropogenic processes within the climate system (IPCC, 2001)

Climate change- any change in climate over time, as a result of human activity or natural variability that alters the composition of the global atmosphere (IPCC, 2007**)**

Climate smart Agriculture- is a fundamental approach to address the interlinked challenges of climate related risks, ecological sustainability and food security (Steenwerth *et al*., 2014; Lipper and Zilberman *et al*.,2018). They have significant potential for addressing the three pillars, such as production for food security, adaptation, and mitigation to achieve sustainable development goals (FAO, 2013).

Adaptation - refers to adjustments in economic systems, social or ecological, in response to actual or expected climatic stimuli and their effects, which moderate potential damages or benefit from opportunities (IPCC, 2001)

Adoption- defined as ‘a change in practice or technology used by economic agents or a community (Zilberman *et al*., 2012). The decision to use and choice new technologies to acquire and use a new innovation. The degree of use of a new technology in a long-run equilibrium when the farmer has full information about the new technology and its potential at the farm level

(Feder *et al*.,1985). In this study adoption of climate smart technologies is a critical component of agricultural adaptation.

Food security - refers to the situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2019b).

Effectiveness: refers to the capacity of performance action to achieve its expected or target objectives and can be measured by robustness to uncertainty and flexibility, that is the ability to change in response to transformed conditions (Dolan *et al*., 2001). In this study it is used to evaluate outcomes and impacts of climate smartness as adaptation strategies and their importance at farm level of household farmers. It is measured by increased number of CSA indicators in terms of food security and adaptation pillars

2.2. Climate variability and its impacts on agricultural production

Climate variability is directly and indirectly affected smallholder farmers, particularly in Africa due to dependence on rain-fed agriculture through widespread changes in rainfall and temperature patterns, as well as frequent and extreme drought, flooding events, inequitable land distribution, and other problems (Lipper *et al*.,2014). Climate related risks are expected to pose more challenges and further reduce the performance of the economy (Arndt and Tarp,2017). In Africa these changes became apparent starting in about 1975, and since then temperatures have increased at a rate of about 0.03 °C per year (Hartmann *et al*.,2013). The agriculture sector is particularly vulnerable to climate change because changes in climatic factors such as temperature and rainfall have a direct bearing on crop and animal production systems since the sector is inherently sensitive to changes in local and global climatic conditions.

Ethiopia is characterized by diverse climatic conditions ranging from humid to semi-arid environments. The climate system is largely determined by the seasonal migration of the inter tropical convergence zone (ITCZ) and a complex topography (NMA, 2001). Changing climatic conditions mostly affect the country mainly due to its high dependence rain fed agriculture, higher reliance on natural resource base and low adaptive capacity (World Bank,2010; Paulos Asrat and Belay Simane, 2018). In Ethiopia, climate variability and change manifested by increasing trend in temperature and decreasing trend in rainfall (NMA,2001). Average annual rainfall distribution ranges from a maximum of more than 2,000 mm over the southwestern highlands to a lower minimum of less than 300 mm over the southeastern and northwestern lowlands. The southwest and western regions of the state are characterized by a uni- modal pattern, whereas the remaining parts exhibit a bi-modal rainfall pattern (World Bank, 2006).

The average annual temperature varies widely, from lower than 15°C in the highlands to more than 25°C in the lowlands. Yields of key cereal crops are mostly likely to decline due to temperature rise and decreasing water availability, with significant implications for commercial investment and agricultural productions. The most significant impacts of temperature rise on crop agriculture were largely concerned with impacts on water availability, soil moisture and fertility, including possible expansion of pest and disease (FAO, 2017).

Increasing or decreasing rainfall coupled with climate variability and changes has negative implications on agriculture and livestock production system. This causes a direct effect on the timing and duration of crop growing seasons and plant growth in farming system (Yilma Seleshi and Zanke, 2004; Rosell,2011). In addition, spreading and distribution of pest and disease vectors towards plant and livestock will likely increase in incidence and spread into new territories, bringing further challenges for agricultural productivity (Wilkinson *et al.*, 2011; Gupta *et al.*,2018). It also affects the quality and quantity of the forage that can be produced in farming system. Livestock is an important source of food (such as meat and milk and other dairy products), animal products, income, insurance against crop failure (Mendelsohn, 2007).

As a result, the concept of adaptation to climate change has become an important aspect at different levels (Howden *et al.*, 2007). Identifying wide range of adaptation responses such as climate smart option based on mixed crop and livestock is essential. Ethiopia settled a national adaptation plan for action NAPA and NMA in 2007. The NAPA identified priority projects largely focusing on institutional capacity building, improving natural resources management, enhancing irrigation agriculture and water harvesting, and strengthening weather early warning arrangements. Recently, Ethiopia published its vision for a climate-resilient economy or CRGE (EPA, 2011). Despite these policy efforts, studies on climate change impacts and adaptation options are limited, which may disturb policy formulation and decision making in terms of planning adaptation strategies.

Moreover, anticipating the impacts of future climate change and evaluating potential adaptation options for various climate change scenarios is highly relevant for agricultural production and improving food security. Actions to make agriculture, sustainable are among the most effective measures to help nations adapt to and mitigate climate change relevant to the goals of climate smart agriculture strategies for enhancing resilient and adaptive to achieve sustainable development goals.

2.3. The Concept of Climate Smart Agriculture

Climate Smart Agriculture (CSA) is an approach to guide the management of agriculture in the era of climate change. The concept was proposed in 2009 and reorganized through inputs and interactions among multiple stakeholders involved in developing and implementing the idea (Lipper et al., 2018). It is well-defined and presented in 2010 by FAO at The Hague Conference on agriculture, food Security and climate change, to achieve the three fundamental principles (environmental, economic and social) of sustainable development by jointly addressing the three main pillars (FAO, 2010). Accordingly, increasing agricultural productivity, to support an equitable increase of a farm income, food security and development for sustainability, building resilience to climate change at multiple levels and reducing or removing greenhouse gas emissions, from agriculture.

CSA is not a new production system, but a means of identifying which production systems and enabling institutions are best suited to respond to the challenges of climate change for specific locations, in order to maintain and enhance the capacity of agriculture to support food security in a sustainable way (FAO, 2010; Lipper *et al*.,2014). It is an approach that requires site-specific assessments of the social, economic and environmental conditions to set a global agenda for investments in agricultural research and innovation by linking the agriculture with development and climate change communities under a common brand (Neufeldt *et al*., 2013).

It also wishes for a set of actions by decision-makers from the farm to the International level to transform agriculture toward climate-smart Pathways (Lipper *et al*., 2014). Implementing the framework of CSA to specific agricultural practices or approaches includes, such as landscape approaches (Scherr *et al*., 2012), sustainable intensification (Campbell *et al*., 2014); safe operating spaces (Neufeldt *et al*., 2013); or a gender and nutrition-smart approach (Beuchelt and Badstues, 2013). While newly framed as a concept for the climate change and agricultural development communities, climate-smart agriculture can include many of the field- and farm-based sustainable agricultural land management has approached already in the literature to improve farmer resilience through stabilizing yields and reducing exposure and impact of, short-term risks to farmers(Bell *et al.*, 2018).

Whereas not all CSA practices, interventions essential achieve all three pillars, promoters argue that it is important to consider exchange and co-benefits between them (FAO, 2013; Lipper *et al*., 2014). It is expected to address climate-related risks by simultaneously considering three main objectives and by fully accounting for the trade-offs and synergies between them (Rosenstock *et al*., 2016).

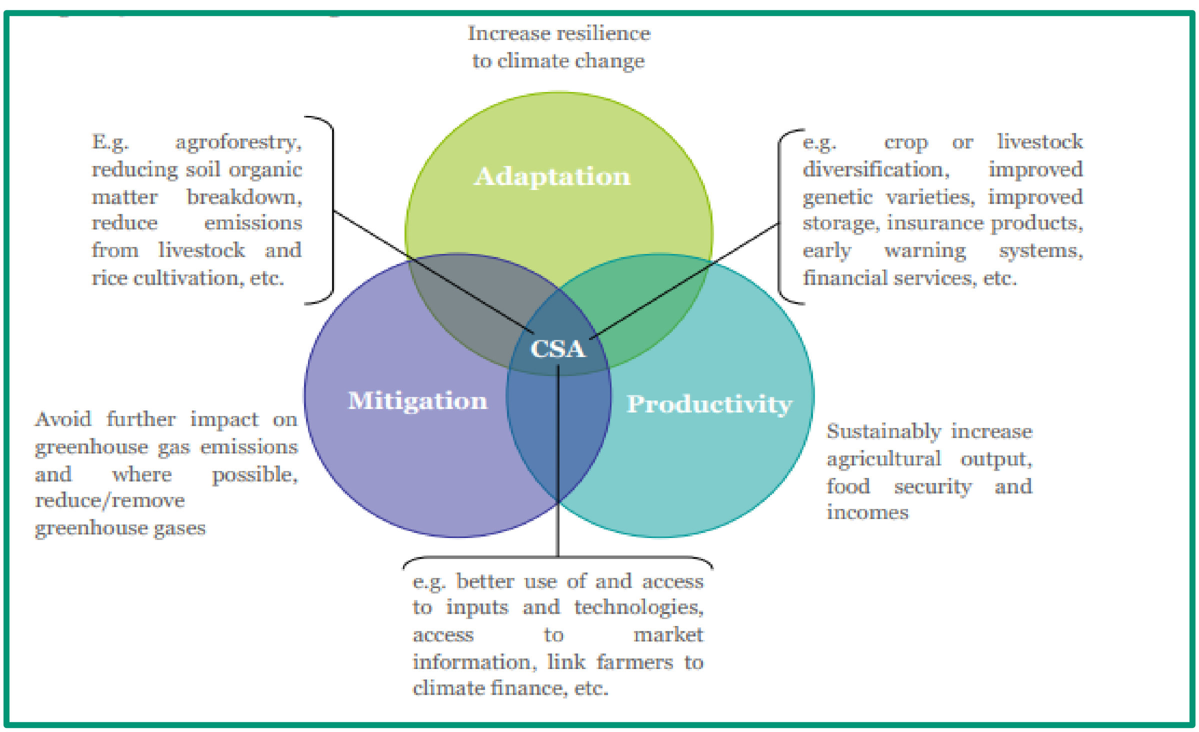


Figure 1.Tradeoffs between three climate smart agriculture pillars (Source: FAO,2013)

With its importance in assessing trade-offs and synergies between its three main objectives, as well as the barriers to adoption, which addresses one of the most essential issues in sustainable agriculture.

2.4. Adoption of climate smart agricultural practices

Agricultural technology adoption is important strategies for the realization of agriculture's performance under changing climate regime. New technology like Climate smart agriculture to enhance food security and poverty reduction, by potentially increasing the income of farming households as well as reducing the market price of staple foods (Lipper and Zilberman, 2018).

Climate-smart agriculture includes different technologies and practices which improves the aims of sustainable development goals. It also includes innovative practices such as better weather forecasting, early-warning systems and risk insurance. An adaptation of CSA technologies can happen in many ways; from the specific field to landscape level (Ibid). CSA increase crop yields, enhance carbon content in soils and maintain soil moisture, under certain conditions (FAO, 2014). When CSA is used in highland areas, it may more enhance crop production and resilience, even in highly degraded soils, due to the interactive effects of improved plant nutrition and soil moisture. A study conducted by Rosegrant *et al*. (2014) confirms that adopting new technologies and alternative practices has the potential to decrease adverse climate related risks. It is concerned field based and farm- based sustainable agriculture management practices and wide in use as well as innovative practices and technologies that promote agricultural Productivity and generate income. It also boosts resilience to climate change and mitigates greenhouse gas (GHG) emissions when possible (Scherr *et al*., 2012; Rosenstock *et al*., 2016; Totin *et al*., 2018)

Ethiopia actively promotes the use of CSA to assist farmers improve their livelihoods and buffer against climate variability and change (Melaku Jirata *et al*., 2016). Studies conducted by Temesgen Deressa (2014) and Amogne Asfaw *et al*. (2018) revealed that the use of different crop varieties, early and late planting, soil conservation, tree planting and irrigation, mixed crop and livestock farming systems and changing planting dates the dominant adaptation methods practiced in the country. Selected smart practices and technologies such as improved variety, small scale irrigation, tree planting, Crop-livestock diversification and improved forages are proposed as an adaptation option in this study.

Table 1. Definitions agricultural practices and justification for being climate-smart

CSA Practices	Definitions	Why it is climate smart
Improved Varieties	Use of genetically improved germplasm specifically bred for traits such as increased yield, stress tolerance and/or disease resistance.	• Restoration of degraded lands healthier livestock; • Improved income from market price; meat & milk for household consumption • Increases in yield and quality at harvest. • Reduces yield loss due to pests and diseases in periods of adverse climatic conditions
Small Scale Irrigation	Transporting and supplying water to crops, making use of labor saving or increased-efficiency technology, either on a large scale, such as a canal/pump system, or as a smaller micro-irrigation scheme.	• Compensation for drought or reduced • Rainfall Food security: diversification of production through facilitating home gardens; reduced risk of crop loss

		• Improved Yields • Creating carbon sinks
Tree Planting		• Resilience and support food security • Storage large quantity of carbon monoxide
Crop-livestock Diversification & other good practices	Farming systems where crops and livestock "form integrated components of a single system	• Ensuring food security • Resilience to weather variability • Improved Incomes • Improved soil productivity, lower requirements Inputs
Improved Forage	Feeds of high variations in composition. Deliberate sowing of easily digestible or high-protein forages, including selected undomesticated grass and legume species and genetically improved varieties	• Restoration of degraded lands healthier livestock; improved income from market price; meat & milk for household consumption • Increases milk and meat yield and income. • Improves efficiency in natural pasture management. • Increases availability of pastures/forages during extreme weather conditions

(Source: FAO, 2016a)

2.5. Factors affecting adoption of climate smart agricultural practice

Climate smart agriculture offers the promise of a locally-adapted, low-external-input agricultural strategy that can be adopted by the poorest and most vulnerable farming communities, as well as can afford varying levels of mechanization and external inputs. Despite its potential, however, CSA adoption in Africa is low, specifically in eastern Africa (Asfaw *et al*.,2016; Suleman, 2017; Aggarwal *et al*.,2018). In agriculture, a number of technology adoption constraints have been identified. There are numerous important issues and problems related to the practice of CSA in Sub-Saharan Africa (Ibid). In many regions, especially those with high population density, low rainfall, or highly degraded land, farmers may find it difficult to allocate crop residues and other biomass to mulching their fields, given the competing demands for these materials for fuel, livestock fodder, and other purposes.

Drawing on existing literature (World Bank, 2013; FAO, 2017) numerous factors limiting the adoption of CSA practices and technologies summarized as: socioeconomic factors, demographic factors and institutional factors, farm characteristics, characteristics of the technology and systems of information transmission. In terms of farm characteristics, factors affecting the adoption decision of farmers such as farm size (Solomon Tarfasa *et al.*, 2018), ownership, and tenure (Menale Kassie *et al*., 2015; Hailemariam Teklewold *et al*.,2019) and for household characteristic factors, age positive effect (Abrham Beyene *et al*.,2017) and negative affect (Asnake Mekuriaw *et al.,2018*) on decision on farmers. Although factors such as level of education, incomes and farming experience have a positive and negative impact of adopting CSA practices (Hailemariam Teklewold *et al*.,2013).

A study conducted by Samuel Diro *et al*. (2017) on adoption factors affecting soya bean in ilu-ababora indicated that, the age of household head has negatively significant impact on the adoption decision of farmers. Found that Access to extension services is positively and significantly correlated with the adoption climate smart agricultural practices of individual farmers at farmer level (DiFalco and Veronesi, 2013). The influence of household size on the adoption of CSA technologies in response to climate change is uncertain. Household size as a proxy to labor availability may influence the adoption of a new technology positively as its availability reduces the labor constraints (Hailemariam Teklewold *et al*., 2013). As a result, a factor to driving CSA adoption and the understanding of how implemented on the ground as well as encourage the effectiveness of these practices is taking an increasing framework of knowledge, investment and idea related approaches to all stakeholders' consideration in the literature (Robinson-Pant, 2016; Mujeyi *et al*.,2018).

Based on the impression of the above studies in relation to the CSA practices ang technologies in Digalu -Tijo district ,household characteristics (age of household head, sex, family size ,farm size, farming experience, education level, annual income , livestock ownership) and institutional characteristics(access to extension, credit access and access to climate information) may affect the adoption decision of farmers.

2.6. Potential of CSA interventions on food security and adaptation pillars

It is very important to understand the effectiveness of the climate smart agriculture (CSA) practice and technologies for environmental health and sustainable development goals under the aims of climate change. As described by Taylor (2018), climate smartness is defined by a triple win approach: increased productivity, adaptation, and mitigation. Effectiveness is one of the major stages of scaling up of CSA technologies, which represents a general sequence of investments, shifts and outcomes on the path to CSA adoption and impact at different scale (Korten, 1980). In this stage, CSA practices and technologies are identified or developed through farmers, researchers, local leaders and NGOs tested at pilot scale and evaluated for agricultural, socioeconomic and sustainability outcomes.

Effectiveness of CSA intervention depends on whether it leads to food security, adaptation and mitigation benefits in the specific local climatic, socioeconomic, biophysical and developmental context (Williams *et al*.,2015; Rosenstock *et al*. 2016). According to Murage *et al. (*2012) the effectiveness of a dissemination pathway depends not only on the number of farmers that receive information, but also on how successfully that pathway influences the farmers' decision to adopt a given technology.

A recent study that reviewed CSA in 33 developing countries from Africa, Asia, and Latin America, which covers 300 distinct production systems indicates that technologies considered climate-smart demonstrate synergies between productivity, adaptation, and mitigation pillars, revealing opportunities for co-benefits and potential triple-wins (Suva *et al*., 2018). As a result, more than 1,700 unique combinations of production systems and technologies across key indicators like yield, water use efficiency, impact on carbon stocks and others generally confirms that CSA is highly effective (Dinesh *et al*.,2015; Balafoutis *et al.*,2017). There are a variety of approaches to increasing the effectiveness of CSA interventions and metrics for achievement of outcomes and impacts. For example, increased food security may result from changes in availability of food (e.g., Yield), accessibility of food (e.g., increased income), utilization of food (e.g., increased food safety), or stability (e.g., less variable harvests) (Rosenstock *et al*.,2016).

There are a number of studies which attempt to quantify the average benefits of adopting CSA technologies consistent with the productivity and resilience of CSA practices at different level. Examples of literature on the impacts of CSA adoption on crop yields include Arslan et al. (2015) in Zambia and Asfaw *et al*. (2016) in Malawi, CSA is context specific and subject to the priorities of farmers, communities and governments it is being implemented. Lal (2009) reviewed climate-smart generally scored the highest in productivity and adaptation pillars of CSA as well as emphasizing the importance of measures of yield and income in encouraging adoption of technologies prioritization over other pillars. A recent study conducted by Sova et al. (2018) revealed that, globally average smartness of improved varieties, technologies for both productivity and adaptation were 4.37 and 3.57 respectively.

A few studies have focused on the effects of CSA practices at landscape level. For example, a study carried out by and revealed that the decision to adopt a climate-smart strategy leads to an increase in food security in terms of food diversity and stability (Brüssow *et al*.,2018); at farm and field-level (Thierfelder *et al*.,2017). Therefore, many interventions that increase productivity are labelled as CSA without evidence on the other two objectives of the CSA, at least one of which would need to be also documented to qualify any intervention as climate smart technologies, although “triple win” interventions at the field level may be the exception rather than the rule, evidence has to be provided on all objectives to support policies and programs that may wish to promote CSA technologies. Study conducted in five countries in East and Southern Africa such as: Tanzania, Malawi, Mozambique, Zimbabwe and Zambia considered the evidence published in peer-reviewed literature on the effectiveness of technologies and management practices to achieve the objectives of increased productivity, resilience and mitigation It is also included what data and evidence are available on how farm and field management practices affect indicators of CSA outcomes and impacts on at least one of the indicators of CSA pillars (Rosenstock *et al*., 2015). One of the crucial goals of CSA is to produce win-win or win-win-win outcomes across productivity, resilience and mitigation.

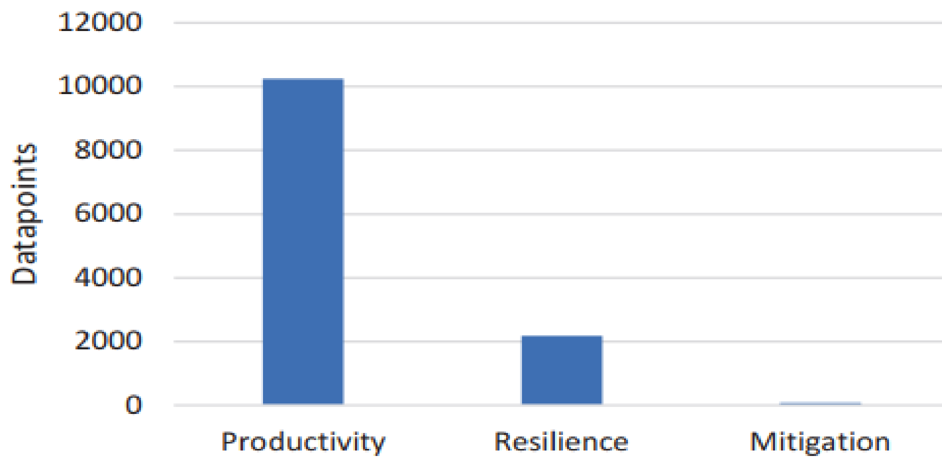


Figure 2.Distribution of outcomes of CSA pillars being studied in East and Southern Africa (Source: Rosenstock et al,2019)

The effectiveness of CSA practices used as adaptation and productivity options vary depending on the farming system (Challinor *et al.* ,2014). Farmers adopt the various CSA practices (Improved varieties, small scale irrigation, tree planting, crop-livestock diversification and combination of the practices) to improve crop productivity in order to finally improve welfare (i.e. Food security, income, nutrition) and adaptive capacity. However, adoption of CSA practices is influenced by perceived positive impacts of CSA technologies, the farm specific characteristics and farmers' socioeconomic characteristics. A recent study conducted by Makate (2019) in south Africa confirmed that CSA adoption at farm-level can improve maize productivity and food adequacy and improve resilience of the farming system to climate change effects.

In crop-livestock mixed systems Climate-smart options vary widely in their potential impacts on agricultural productivity, climate change resilience, and GHG mitigation (Rosenstock et al.,2016). A study conducted by Manda *et al*. (2016) argues that adopting combining different CSAs seems to offer greater benefits on crop yields and household incomes in Tanzania. Increasing the rate of adoption of improved agricultural technologies can help build resilience to weather-related risks. For example, in Ethiopia adopting various of CSAP has a positive and significant impact on crop production (Moti Jaleta *et al.*,2016; Mulat Gebeyehu, 2016). A study carried out by Lamanna *et al*. (2016) and Rosenstock *et al*. (2019) noted that CSA practices evaluated in ways that cross more than one of these three pillars. This is important for development practitioners because it limits the evidence with which to evaluate potential trade-offs and increases the likelihood of unintended consequences with development programming.

Table 2. Potential Impacts of Selected Climate-smart options in mixed farming system available to smallholders in mixed crop-livestock systems in developing countries

CSA Practice	Effectiveness as food security	Effectiveness as adaptation strategies	Strength of evidence	Main constraints to adoption
Improved Varieties	+++	+++	***	High investment costs; high prices of improved varieties
Small Scale Irrigation	++	++	**	Requires investment in infrastructure, Lack of information on seasonal climatic forecast trends, scenarios extension, capacity building

Tree Planting	+++	+++	***	Shortage of land, lack of knowledge & information
Crop-livestock Diversification	++	+++	*	Lack of information on seasonal climatic forecast trends, scenarios Competing demands for crop residue biomass
Improved Forage	+++	+++	**	High costs, unavailable of seed sources

Key: CSA potential: + = low; ++ = medium; and +++= high &Strength of evidence: ***= confident, **likely, *poor (Source: FAO, 2013;2018)

Several studies conducted and summarized by different author's in Ethiopia found that the appropriateness of multiple climate smart agriculture technologies practiced by a farmer was ensure agriculture production and increasing adaptive capacity in the context of climate variability and change in the country from elsewhere (Daniel Asfaw and Mulugeta Neka, 2017; Kebede Walker *et al*.,2018;Asnake Mekuriaw *et al*. (2018) ; Aseres Mamo *et al*.,2019). Climate smart practices could reduce the farmer's vulnerability related to climate risks through effective practices and technologies by creating economic opportunities that help food security and increase adaptive capacity (Lipper *et al*.,2018; Hellin and Fisher, 2018).

Hence increasing awareness about the benefits of CSA practices among smallholder farmers has a potential to boost crop production and improve food security and provide a conceptual basis for assessing the effectiveness of the changes in agricultural practices where climate smart technologies are adopted so as to understand on how to enhance yield and resilience under the prevailing climate variability.

2.7. Conceptual Framework

Figure 1 shows the conceptual framework which CSA is an approach response to climate variability and shocks while providing triple of the three pillars of CSA strategies for sustainable development goals. Addressing one pillar have co-benefits for one another. Improving agricultural productivity and incomes from crops and livestock reduce the exposure of farmers to short-term ang long term climate related risks. Thus, CSA practice enhancing agricultural production have sustainable effect on the livelihood and environment

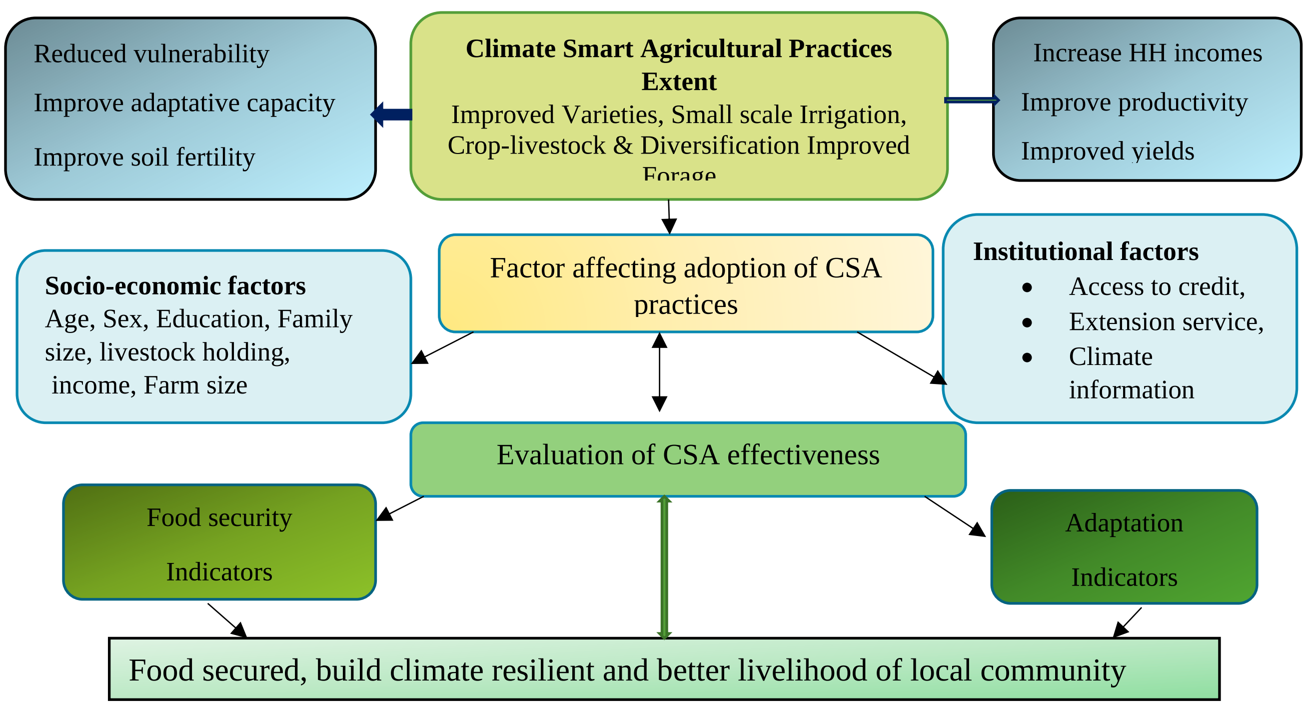


Figure 3. Conceptual framework of the study

3. MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1. Location and Size

The study was carried out in Digalu-Tijo district which is one of the administrative units of Arsi zone. Geographically, it is located between $7^0$39’22’’N to $7^0$77’54’’N Latitude and $39^0$15’59’’E to $39^0$33’26’’E Longitude. The district borders with Shirka district in the southeast, Hitosa district in the northeast, Lemu-Bilbilo district in the South and southeast, Munessa district in the West and southwest and Tiyo district in the North, northeast and northwest. The district has a total area of 927.4 Km^2 which accounts for 4.41% of the total area of Arsi Zone (Milkesa Tufa, 2018)

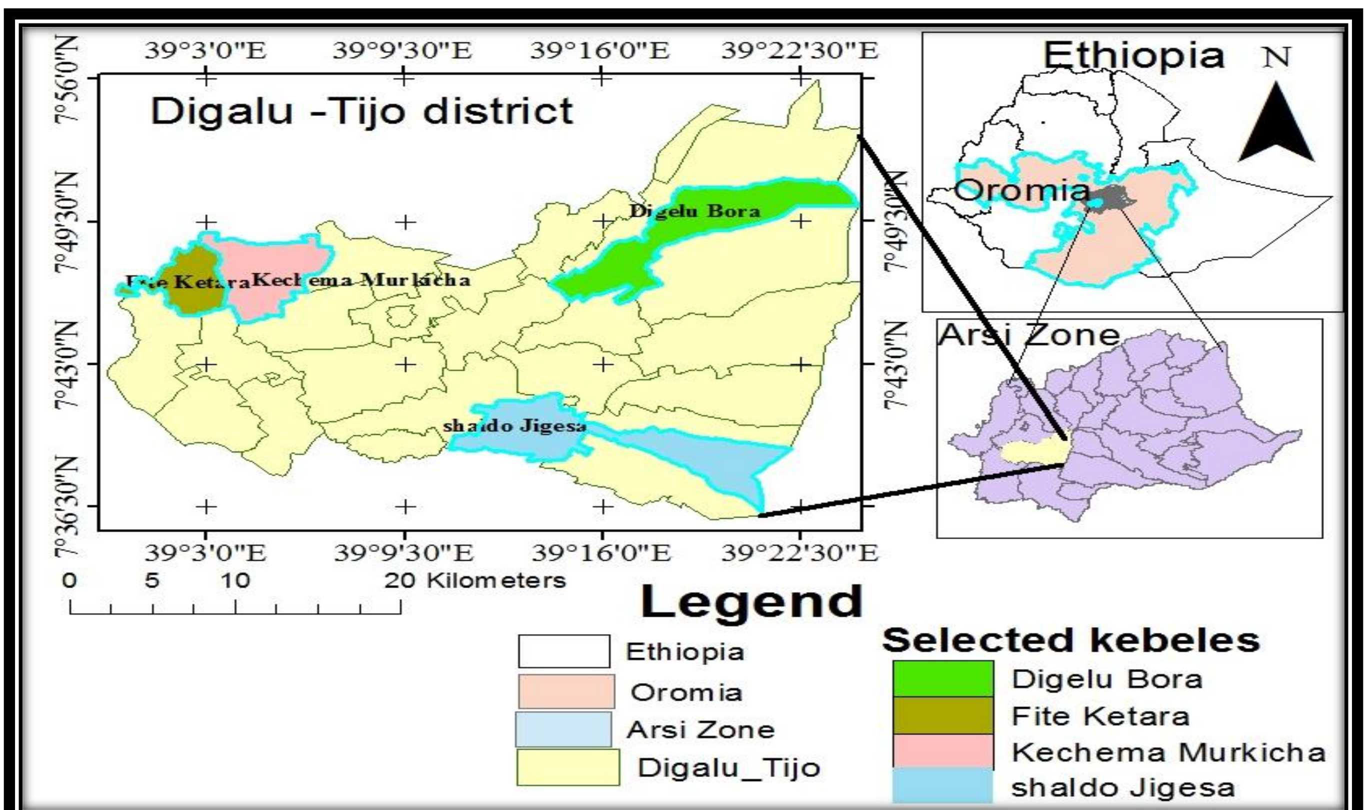


Figure 4. Location Map of Study Area

3.1.2. Climate

The mean annual minimum and maximum temperature of the study area is 9.4°C and 21.2°C respectively. The study area receives an annual rainfall of 690-1400 mm. The rainfall pattern is bi-modal, which are Arfaasa (short rainy season) from March to May and Ganna (long rainy season) from June to September. Due to its altitudinal location, the climatic condition of the district is dominantly Dega (highland) which has a temperature of 10^{o}C to 15^{o}C with altitude ranges from 2500-3560 meter above sea level in elevation. This type of climate consists of about 78% of the total area of the district. The remaining ones are Woyina Dega (midland) having a temperature range from 15^{o}C to 22^{o}C.

3.1.3. Topography and Drainage

The relief structure of the district consists of mountain ranges of Chilalo Galema range, undulating high plateau separated by major and small rivers of the district and low flat plateau. The altitude of the district is ranging between 2500 masl in Lole area to 3600 masl on Bora Luku area. Due to its location, the district has high network of river systems. The major permanent rivers of the district are Ketar, Ashebeka, Gusha, and Temela. On the other hand, the major seasonal streams are Dangalati, Danisa, Girisa, Sokora, Nanawa and korsa. Generally, the district has high potential for both traditional and modern irrigation system which can be used to increase agricultural productivity if they are utilized efficiently (Kassim Dedefo, 2018).

3.1.4. Soils

The major types of soil in the district are Pellic Vertisols that covers more than 85% of the total area of the district. In addition Orthic Lome soils and Mollic sandy soils cover some parts of the district (Kassim Dedefo, 2018)

3.1.5. Vegetation

The vegetation, including Afro-Alpine on the top of chilalo Galema mountain range, Natural forest like Tid, Zigba, Bisanna, Koso, Shola, wanza adjacent to Afro-Alpine vegetation at high altitude of the district and along the upper course of the major rivers of the district. In addition, the district has also grassland vegetation in its southern part commonly known as Lukuche areas of the district. Regarding government protected/public forests, 1109 hectares forests like Lukuche forest 928.695 hectares and Digelu forest 180.305 hectares are found in the district. There are also about 1500 hectares of community forest in the district (Abayneh Derero, 2012).

3.1.6. Population of the study area

The total population of the woreda is about 140,460 and on this the rural and urban population is About 126,386 and 14,080 respectively. From the total populations of the district 23% and 73% living urban and rural area respectively. An overall sex ration 49% and 51%, male and female respectively in the district. The young age population (0-14), productive age population (15-64) and old age population (65+) accounts for 49.97%, 44.82% and 5.21% of the total population respectively (Tesfaye Hailu and Mekonnen Addis, 2015).

3.1.7. Major economic activities

The district is known for its high potential for crop and livestock production. People living in Digalu Tijo depend on a mixed farming system which is defined as a combined production of both crop and livestock production. Major crops grown in the district are wheat, barley, maize, bean, pea and other pulse crops. Cattle, sheep and goat are among the livestock species, predominantly reared. The cattle population in the district are 183624, 107645 sheep, 9715 goat, 23709 horse, 12303 donkey, 4415 mule, 63062 poultry (Kassim Dedefo, 2018). Furthermore, cash crops such as vegetables and oilseed crops are grown.

3.2. Sampling technique and sample size determination

Digalu-Tijo district, within the Arsi Zone of Oromia regional, state was selected based on its agricultural potential and wide practices of climate smart agriculture. A multistage stratified random sampling technique was employed to select farm households. In the first stage, 23 kebeles within the woreda were stratified into agro-ecological zones as Dega (highland) and Woyina Dega (midland). In the second stage, two Kebeles from each agro ecological zone, totally four kebeles were selected purposively based on agro-ecology, accessibility and presence of CSA adopters. In the third stage, 150 households within the selected kebeles were selected using simple random sampling technique proportional to the total number of farm household heads. To determine sample size, a formula developed by Kothari (2004), was applied as follows.

$$n = \frac{Z^2 * N * p * q}{e^2 (N-1) + Z^2 * p * q}$$

Where; n is the sample size, z is 95% confidence level (α= 0.05) is 1.96, Z^2*=4 p= 0.5 is the proportion of the population of interest, smallholder farmers (proportion of successes). Variable q is the weighting variable (proportion of failures) and this is computed as 1-p, and* e^2 *= 0.08 is an acceptable error (precision), N= 3588 and the sample calculated n= 150 which is the necessary sample size of the study.*

Table 3. Total household heads and Sample Size in Kebeles

Sample Kebeles	Total households in Kebeles	Sample Size	Agro Ecology
Digalu Bora	920	38	Highland (Dega)
Shaldo Jigessa	838	35	Highland (Dega)
Kechema Murkicha	1095	46	Midland (Woyina Dega)
Fite Ketara	735	31	Midland (Woyina Dega)
Total	3588	150	

(Source: Digalu-Tijo Woreda ANR, 2019)

3.3. Data collection

Both qualitative and quantitative data were collected for the study from both primary and secondary sources. The primary data were obtained through household surveys, focus group discussions (FGD), key informant interviews, and field observation using semi-structured questionnaires. Secondary data were gathered from published sources such as journal articles, conference proceedings and reports on the CSA technologies were gathered from published and unpublished documents like annual reports. Secondary data on the district profile was also gathered from the Digalu - Tijo district to give a description about the study site.

3.4. Method of data collection

3.4.1. Household survey

Household survey was employed to collect the quantitative data using questionnaires. The questionnaires were pre-tested and four enumerators who speak the local language were recruited and trained for the survey. Enumerators visited each of the 150 sample households for interview to get information on household characteristics (family size, livestock holding), access to extension services, types of CSA practices adopted, factors determining CSA adoption. Both open and closed ended questions were used. The questionnaire was prepared in English and latter translated to local language, Afan Oromo which is the widely spoken in the area.

3.4.2. Key informant interview (KII)

Nine key informant interviews were arranged with selected female and male headed households in order to get relevant information about their awareness on climate variability and adoption of CSA practices. Likewise, four agricultural development agents from the sample kebeles and three experts at Digalu-Tijo woreda agricultural and natural resource bureau, one expert of from land administration bureau and one expert from water and irrigation bureau were interviewed to collect primary information about awareness, constraints and adoption of CSA practices among rural farmers.

3.4.3. Focus group discussion (FGD)

Focus group discussion were conducted to obtain the general information on the importance of CSA and its challenges and opportunities of CSA adoption. Focus group discussants were purposively selected to include different social group representatives. Accordingly, eight focus group discussions were made with involving of 32 participants. The information obtained through focus group discussion were used to triangulate and scrutinize the information collected through household survey.

3.5. Methods of Data Analysis

Both descriptive and inferential statistics were used for data analyses. The data were summarized and analyzed using Statistical Package for Social Sciences, (SPSS Version 23), Stata Version15 and Microsoft Excel (2013). The multinomial logistic regression model was used to analyze the factors determining the choice of climate smart agricultural practices in the study area. Analytic Hierarchy Process Method was used to evaluate the effectiveness of CSA interventions in the study area.

3.5.1. Descriptive Data Analysis

Data collected from site observation and household survey were analyzed using descriptive statistics. Frequency distribution, percentages, mean, standard deviation and cross-tabulations were used to summarize, present and interpreted survey results such as demographic, socioeconomic, institutional factors. Likert Rating Scale was used to analyze the perception of farmers regarding the effectiveness of the adopted CSA technologies in reducing climate related risks, and others.

3.5.2. Econometric Data Analysis

In order to identify factors that affecting the farmers' decision of adopting climate smart agricultural practice in the way to respond to climate related risks, discrete choice models like logistic regression (where there are only two options) and multinomial logit model, whenever the options are three or more, are widely used (see, for example, Temesgen Deressa *et al*. 2009; Abayneh Amare *et al*., 2017;Brüssow *et al*.,2018; Demissie Gelashe,2018; Sadik *et al.*,2019). Likewise, MNL was employed in this research because it permits the analysis of decisions for more than two categories. MNL gives the choice probabilities of each alternative as a function of the systematic portion of the utility of all the alternatives. The multicollinearity problem among the explanatory variables was tested using variance inflection factor (VIF) and Contingency Coefficient (CC) for continuous and dummy explanatory variables, respectively (Greene, 2003). Basically, multicollinearity problem may arise due to a linear relationship among explanatory variables and the problem is that, it might cause the estimated regression coefficients to have wrong signs value. A VIF value greater than 10 is refers to a signal for the existence of a multicollinearity problems among explanatory variables. Likewise, the decision rule for contingency coefficients is that when its value approaches usually if it exceeds 0.75, there is a problem of association between the dummy variables. Breusch Pagan test (hettest of STATA) was conducted to assess the presence of heteroscedasticity in the model.

Overall model fitting and the validity of the assumption of independence of irrelevant alternatives (IIA) tests were checked using the Hausman test before running the model. The IIA assumption requires that the probability of using a certain adoption CSA practice by a given household is independent of the probability of choosing another adoption CSA practice. Respondents had selected only one category based on their major adaptation strategy. The decision of whether to use any adaptation option or not could fall under the general framework of utility or profit maximization.

For CSA adoption with different categories the calculations require of M-1 equations, one for each base category relative to reference category, it explained the relationship between adaptation option and the variables in different categories. The model is specified as follows

Hence, if the first categories are the reference, then for m=1,2… m11

$$ln\,\frac{P(Yi=m)}{P(i=1)} = \alpha_{m+} + \sum_{K=1}^{k} \beta_{mkx_{ik=z_m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Hence, for each case their id will be of M-1 predicted log of M-1 one for each category relatives refence category or base category (Note that when m=1 you get ln (1) =0=2_{11}, and exp (0) =1 When there are more than two groups, computing probability is more complicated in MN logistic regression. m=2…, m11 for General Equation (Green, 2003)

$$P(Y_{i=m}) = \frac{exp\ (Z)}{1+\sum_{h=2}^{M} exp\ (Zhi)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

For categories, $\mathbf{P(Yi=1)} = \frac{1}{1+\sum_{h=2}^{M} \exp\ (Zhi)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3)$

The estimated coefficients of the multinomial logit model provide only the direction of effect of independent variables on dependent variables, but estimate neither represent the actual magnitude of change nor probabilities (Chilot Tizale, 2007; Greene, 2018). Instead, the marginal effect measures the expected change in the probability of a given choice that has been made in relation to the unit change in the explanatory variable. Thus, the Stata version 15 was used to generate the parameter estimates (marginal effect). As a result, the marginal effects are usually derived to estimate the effects of the independent variables on the dependent variables.

The major responses (CSA practices) adopted by smallholder farmers were categorized into six categories based on their similarity in character as improved varieties, small scale irrigation practices, and multi-purpose planting trees, crop -livestock diversification, improved forages and no adaptation (as a base category).

3.5.3. Analytic Hierarchy Process (AHP) Analysis

In order to evaluate the effectiveness of climate smart agricultural practices at farm level, the contribution of newly introduced practices is taken into consideration with respect to their level of importance. CSA options should be assessed for their effectiveness in achieving the predictable climate change. However, there is a lack of clear and workable criteria and methods for assessing the actual climate-smartness in diverse farming system. Multi criteria decision making techniques can be applied to assess value judgments of individual decision makers or multiple stakeholders for assessing the effectiveness of CSA interventions based on their experience, knowledge and perception at farm level are widely used (Abdollahzadeh, 2016; Manda, 2016; Manda *et al*.,2019). Likewise, Analytic Hierarchy Process (AHP) was employed in this study because it helps decision makers choose the best solution among several alternatives across multiple criteria.

AHP is a form of multi-criteria analysis that is used to solve complex decision problems where multiple perspectives into account tangible and intangible aspects. It was developed by Saaty (1980) to help decision makers find the option that best suits their goal and understanding of the problem while taking into consideration factors that cannot be quantified. In this study, it was applied to evaluate the implications of newly introduced practices across food security and adaptation pillars only. The impacts of interventions, across food security and adaptation indicators, are easily observable/measurable/estimable by farmers. Evaluating the potential of CSA practices is particularly important for smallholder farmers in the study area to allow better prioritization of interventions for improved food security, adaptive capacity, incomes and minimizing climate related risks for sustainable development goals.

The identification and selection of an appropriate set of CSA indicators depend on recent literature and relevant guide used to select the basis of any useful impact of the CSA intervention (Williams *et al*., 2015; Quinney *et al*.,2016; World Bank, 2016). Based on these literature and discussions with local experts 14 indicators (four indicators for food security pillar and 10 indicators for adaptation pillar) relevant to CSA are listed in this study. The indicator selection was based on different criteria like relevance, practicability, measurability, applicability and reliability (Van Cauwenbergh *et al*.,2007; Brown, 2009; Lebacq *et al*., 2013).

Accordingly, food security pillar includes, income, consumption, food production and animal production indicators. The food security pillar of CSA focuses on strategies that aim to ensure food productivity, food availability, food accessibility and food utilization (Smith *et al*., 2015; Mittal and Bajwa, 2018). In the case of adaptation pillar 10 indicators were involved: skills and knowledge, access to information, crop adaptation, crop diversity, animal diversity, soil protection, income from farm productivity, stability of farm productivity income stability, and animal adaptation. The adaptation pillar of CSA points towards risk reduction, technological adjustments, and information support for environmental management, sustaining the proper growth and development of crops and/or animals.

Using AHP is evaluating the impacts of climate smart interventions at individual farm level of households as follows. Data collected from HH farmers were subjected to pairwise ranking and scoring, according to a Likert scale. Weights were allocated for each criterion using the AHP following Saaty (1980). A pairwise comparison of indicator importance and indicator scoring, which involves the careful process of allocating weights (Notenbaert *et al*. 2010). One advantage of using ranking weight methods is that data, information relies only on ordinal (ranking) of criteria importance (Roszkowska, 2013).Comparisons of the importance of the indicators were entered into a matrix with a 1–9-point scale, where a value of 1 expresses "equal importance" and a value of 9 represents "extreme importance".

Following this, in AHP, consistency index (C.I.) and consistency ratio (C.R.) were applied to measure the consistency of the pairwise comparison matrix. Saaty (1980) developed the Consistency Index (*CI*) of the square matrix *A*. This measure can be used to verify if the measure the judgments supplied is consistent.

$$\mathbf{CI} = \frac{(\boldsymbol{\lambda max} - \boldsymbol{n})}{\boldsymbol{n} - \mathbf{1}}$$

Where: λmax is the highest value of the matrix *A*.

The calculated priorities are plausible only if the comparison matrices are consistent or near consistent. The approximate ratio of consistency can be obtained using the degree of inconsistency of the square matrix *A and can* be measured by the ratio of *CI* to *RI*, which is called the Consistency Ratio (*CR*).

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \boldsymbol{x100\%}$$

Where RI is the Random Consistency Index, which is the average CI of a randomly generated reciprocal matrix with dimension (Saaty, 1980). Finally, the matrix is sufficiently consistent and acceptable if the matrix $CR \leq 10\%$. According to Saaty (1988), if the CR value is much in excess of 0.1, the judgments during pairwise comparison are untrustworthy because they are too close for randomness.

Based on these weights, the aggregated food security and adaptation indices were calculated following a three-step process. First, the intervention was scored for each indicator within the food security and adaptation pillars. Farmers were asked to assess whether there had been an increase in the indicators since starting the intervention. Then, using the Likert scale scoring method, point scores from the respondents were calculated for each statement in food security and adaptation pillars were ranked in order of their importance as determined by the weights of the responses. The 5-point Likert-type rating scale was categorized as Strongly disagree (SD) = 1, Disagree (DA) = 2, Neutral (N) =3, Agree (A) =4 and Strongly Agree (SA). The mean score of respondents based on the 5-point Likert-type rating scale was computed; where, in scores ranging from 1 to 5, a score of 1reperesnts that the farmer strongly disagrees, and 5 meaning that the farmer strongly agrees that the indicator has increased since he/she began the intervention.

3.6. Description of variables and hypothesis on adoption decision model

3.6.1 Dependent variable

The dependent variables of this study were climate smart agricultural practices as adaptation options that farmers adopted in response to climate related risks. In the current study, based on information from literature and knowledge in the area, the following response variables were selected and coded as follows: No adaptation (0), Improved Varieties (1), small scale irrigation (2), Multipurpose tree planting (3), Crop-livestock diversification (4) and Improved forages species (5).

3.6.2. Independent variables

The independent variables are the factors that affect the adoption of CSA practices as adaptation options to climate variability**.** In the current study, the following explanatory variables hypothesized to explain the adoption decision of CSA practices were selected:

Agro- ecology: It is a dummy variable coded 1 if Dega (highland), 2 Woyina Dega(midland). This variable was expected to have a positive or negative sign in relation to adoption of CSA practices.

Sex of household head: it is a dummy variable, coded 1 if the sex of household head is male or 0, if female. This variable was expected positive or negative sign.

Age of household head: It is a continuous variable measured in years and represents experience of the household head in farming. Therefore, this study hypothesized that the age of the household head may have a positive or negative effect on adoption of climate smart agricultural practices.

Family size: It is measured by the number of family members in the household and is a continuous variable. It is anticipated that it may have a positive or negative effect on adoption of CSA practice.

Land holding size: It is a continuous variable measured in hectares. Land holding size is the total land holding of farming household. It is expected to have a positive effect on adoption of CSA practices.

Farming experience: It is the total number of years of experience a respondent household head has in farming and is a continuous variable. The longer farming experience, the higher is the probability of a farmer adapting to climate variability. Hence, it is expected that farming experience of household head positively affects the adoption of CSA practices.

Education of household head: It is a continuous variable measured in number of years stayed in school. Education supports adoption of improved technologies and enables to easily understand the situations. In this study, education of household head is expected to positively or negatively influence household's adoption of CSA practices.

Livestock ownership: It is continuous variable that refers to the total number of animals owned by the household measured in total livestock unit (TLU). Livestock is considered as another asset which is a security against crop failure. This can be attributed to increase wealth and income base of farm households which makes more money available in the households. Hence, this variable is expected to be positively influenced household's adoption of CSA practices.

The annual income of the household: This is a continuous variable and refers to the annual income of households which is playing an important role in the uptake of CSA practices. Therefore, an increase in the availability of family income is expected to be positively influenced household's adoption of CSA practices.

Access to climate information: It is a dummy variable coded 1 if the household had access to information on climate, 0, otherwise. Hence, this variable is expected to positively influence household's adoption of CSA practices.

Access to extension services: This is a dummy variable; coded 1 if the household used extension service and 0, otherwise. In this study, the availability of extension services is expected to positively influence household's adoption of CSA practices.

Access to credit service: This is a dummy variable coded 1 if the farmer had access to credit and 0, otherwise. Credit service alleviates the financial constraints faced by the farmer and hence enhances the probability of adopting CSA technologies. This variable is also expected to have positive influence household's adoption of CSA practices.

Table 4. Description of variables and hypothesis on adoption decision model

Variables	Description and Unit of Measurements	Expected sign
Dependent Variable		
CSAPs adopted as adaptation option	It is Categorical variables: 0 for not using any adaptation option, 2 for Improved varieties, 3 for using small scale irrigation, 3= adopting trees planting, 4= using crop-livestock diversification and 5=Improved Forage	

Independent Variables		
Agro ecology	Dummy, 1=Woyina Dega, 2=Dega	+/-
Gender	Dummy, 1=male, 0=female	+/-
Age	Continuous (years)	+/-
Family Size	Continuous (number)	+/-
Land holding size	Continuous (years)	+
Farming experience	Continuous (Hectare)	+
Education Level	Continuous (Years)	+/-
Livestock ownership	Continuous, (TLU)	+
Total Annual income	Continuous (ETB)	+
Access to climate information	Dummy, 1=Yes, 0=no	+
Access to extension	Dummy, 1=Yes, 0=no	+

4. **RESULTS AND DISCUSSITIONS**

4.1. Demographic and socioeconomic characteristics of the respondents

The average age of respondents was 41 years, which implied that most of sample households were in the productive age group (Table 5). The average family size in the study area was 6.56 years (Table 5) which is high compared with the national rural average of 5.31 (CSA, 2014). This indicated that the presence of high fertility rate in the area. A study carried out by Mona and Nhemachena (2006) indicated that the large household size is mostly inclined to divert part of its labor force into non farming activities to generate more income, which increases the chances of adapting to climate related risks.

The results of the study indicated that respondents had an average of 22 years of farming experiences and own average farm size of 1.98 ha of land (Table 5) which was higher than national average land holding of 1.4 ha (CSA, 2013). This implies a positive implication in adoption of CSA practices. The bigger the farm size, the bigger is the proportion of land allocated to adapt crop and livestock adaptation option and reduce climate related risks (Farid *et al.,* 2015; Dunnett *et al.*,2018). The average schooling, stay was 3.54 but some attended up to 12th grade. A study conducted Mwangi and Kariuki (2015) confirmed the more educated a farmer is, the easier he or she adopts modern technology.

The average herd size of the respondents was 4.34 TLU but some keep up to and 9.41 TLU and they received average annual income of 1,62,760 Ethiopian birrs in 2017/18 cropping season. A recent study by Assefa Agidew (2019) in the northeastern highland of Ethiopia revealed that a positive relationship between the quantity of livestock owned and the adoption of CSA practices.

The results show that, 77 percent of the sampled households were male headed with female headed households comprising 23 percent. Male-headed households have better access to technologies and climate information than female households due to freedom of mobility, participation in different meetings and trainings (Temesgen Deressa *et al.*,2008).

This study also found that about 71percent of participants accessed extension services while 29 percent did not. In terms of credit access, the findings revealed that 77 percent of farmers involved in the adoption of CSA practice had applied for a loan in the last one year (Table 6)

Table 5. Demographic and socioeconomic characteristics of respondents (Continuous variables)

Variables	Unit	Total Number (N=150)			
		Mean	**Std. D**	**Min**	**Max**
Age	Numbers of Years	41	7.52	29	66
Family Size	Number of ind. Family	6.56	2.87	1	15
Land holding size	Hectare	1.98	.821	0.75	4
Farming Experience	Numbers of years	22	8.41	8	48
Education Level	School Years	3.54	2.69	0	12
Livestock Holding	Measured in TLU	4.34	1.42	1.26	9.41
Total Annual Income	Measured in the ETB	1,62,760	75871.6	53128	312876

(Source: Survey Results, 2019)

Table 6. Demographic characteristics and institutional factors of respondents (dummy variables)

Variables	Response	Total Number (N=150)	
		Number	**%**
Gender	Male	115	76.7
	Female	35	23.3
Access to Information	Yes	108	72
	No	42	28
Access to Extension	Yes	106	70.7
	No	44	29.3
Access to Credit	Yes	115	76.7
	No	35	23.3

(Source: Survey Results, 2019)

4.2. **Types of CSA technologies practiced in Digalu-Tijo District**

The results revealed that smallholder farmers in the district have adopted various CSA practices and technologies. Respondents in the midland and highland agro-ecological zones ranked the five commonly practiced CSA technologies differently. In the midland agro-ecological zone improved varieties received the highest score of 36%, followed by crop-livestock diversification with 18% while in the highland agro-ecological zone crop-livestock diversification was received the highest rank (22%) followed by small scale irrigation (21%), tree planting (21%) and improved varieties (9%) respectively (Figure 5). According to Gutu Tesso *et al*. (2012) and Belaineh Legesse *et al*. (2013) farmers living in different agro ecological settings have different choice of adaptation strategies because of differences in climatic condition, soil and other factors.

Given the farmers objectives of maximizing yield per scarcely available land, it was not surprising that adoption of improved varieties ranked first particularly in the mid agro ecological zone where rainfall is relatively lower compared to the highlands. According to Aryal *et al.* (2018) the adoption of improved varieties boosts farmers' adaptive and resilience capacities as well as increasing income through improving productivity to minimize the effects of climate change and variability. The result goes in line with a recent study by Tagel Alemu (2014) in Boricha woreda, Sidama zone, reported that adoption of improved crop varieties had a robust and positive effect on productivity and incomes of households in mid agroecological zones.

Improved crop varieties were the most commonly implemented CSA interventions by the smallholder farmers to reduce the risk of pests and diseases that are accelerated by climate variability (Jellis, 2009; Mittal, 2012; Nyasimi *et al*., 2017)**.** Adoption of improved varieties increase productivity, for a rapidly growing population, promoting food security and higher income to increase resilience to climate variability and hence is an important strategy in adaptation to future climate related risks. Moreover, adoption of stress-tolerant varieties can contribute to the three pillars of CSA by increasing productivity for food security, enhancing the adaptive capacity of farmers and increase the optimal use of available resources for sustainable economic development particularly in rain-fed systems (Branca *et al*.,2011; Thornton and Herrero, 2014; Bekele Shiferaw *et al*.,2014; Makate *et al*., 2016; Khatri–Chhetri *et al*., 2017).

Small scale irrigation is other types of climate smart intervention adopted more by housed hold in the highlands (Dega) compared to midlands (Woyina Dega). This implied that adoption of irrigation varies intensely by geographic area, depending on the availability of water and the farming system. This finding consistent with evidence from Ketar irrigation scheme reported from Arsi zone (Eshetu Tefera and Young-Bohk Cho,2017). Irrigation and improved agricultural water management provide opportunities to cope with the impact of climatic variability through enhance productivity per unit of land and increase the production volume (FAO, 2014).Adopting small scale irrigation technologies in the concept of climate smart agriculture strategies also enables cultivation of land that would not be arable without irrigation technology as well as achieves stability of crop production by maintaining soil conditions , allow some water to seep into the soil (infiltration) and improving the soil to allow more vegetation cover (Mango *et al*.,2018).

Farmers also planted trees as adaptation measures to prevent soil erosion caused by heavy rainfall and used as a source of incomes. The results revealed that households living in the highland agro ecological zone adopting higher as compared households in midland agro ecological zone this may be, due to availability of water as well as protecting crops from climate related risks to ensures soil fertility and farm productivity. This results support by Shongwe *et al*. (2014) who reported that farmers residing in *Dega* areas, having more family size and who perceived the availability of possible adaptation measures to climate change were better at practicing land management options. Tree Planting are key components of many climate-resilient agricultural practices because they may increase and sustain soil health, regulate nutrient and water cycling to increase carbon storage as well as producing fodder, fuel, food and high value products for sale (Luedeling *et al*.,2016; Barrios *et al*.,2018). Moreover, a combination of beneficial trees on farm land and in the landscape level used to, not only provides important ecosystem services, but also leads to a direct increase in income through diversification of products and greater resilience to climate shocks (Verchot *et al.*,2007; Neufeldt, 2013; Mbow *et al*., 2014). In this study area, for examples indigenous species like Hyginia Abysinica (Koso) has spread widely among farmer's field which has good water retention capacity and improves soil fertility.

Crop -livestock diversification is also the main sources of livelihood which supports farmers to have various products and minimize risks due to climate variability and change for growth in study area. It is also used to decrease the effects of adverse weather conditions such as drought, erosion, pests and diseases in the crop season and/or reduction in input requirements to achieve agricultural and livestock production in mixed farming system. This is in line with the finding of Österle *et al*, (2012) and Abrham *Belay et al*. (2017) in the central rift valley of Ethiopia that showed the crop-livestock farming system is used to as adaptation option to climate change as rangeland has been converted to cropland.

Another type of climate smart intervention adopted by smallholder farmers to enhance the feed availability in mixed farming system is improved forages species. The results revealed that households living in the midland agroecological zone adopting higher as compared households in the highland. This may be due to a presence of large cultivable land and having information about feeding livestock a quality fodder. As a result, some farmers are involved in fattening their sheep, cattle and others get good prices. Feed availability close to homestead has also reduced free grazing and the resulting land degradation that impacts on crop productivity. This finding supported by Thornton *et al*. (2018) and Sisay Damtie (2017) who reported that adoption of improved fodder rehabilitates degraded land increase livestock health in the mixed system. In this area forage species such as Acacia saligna, Sesbania, Tree lucer and Alfalfa, Desho grass, Elephant grass, and Rhodes grass adopted by households.

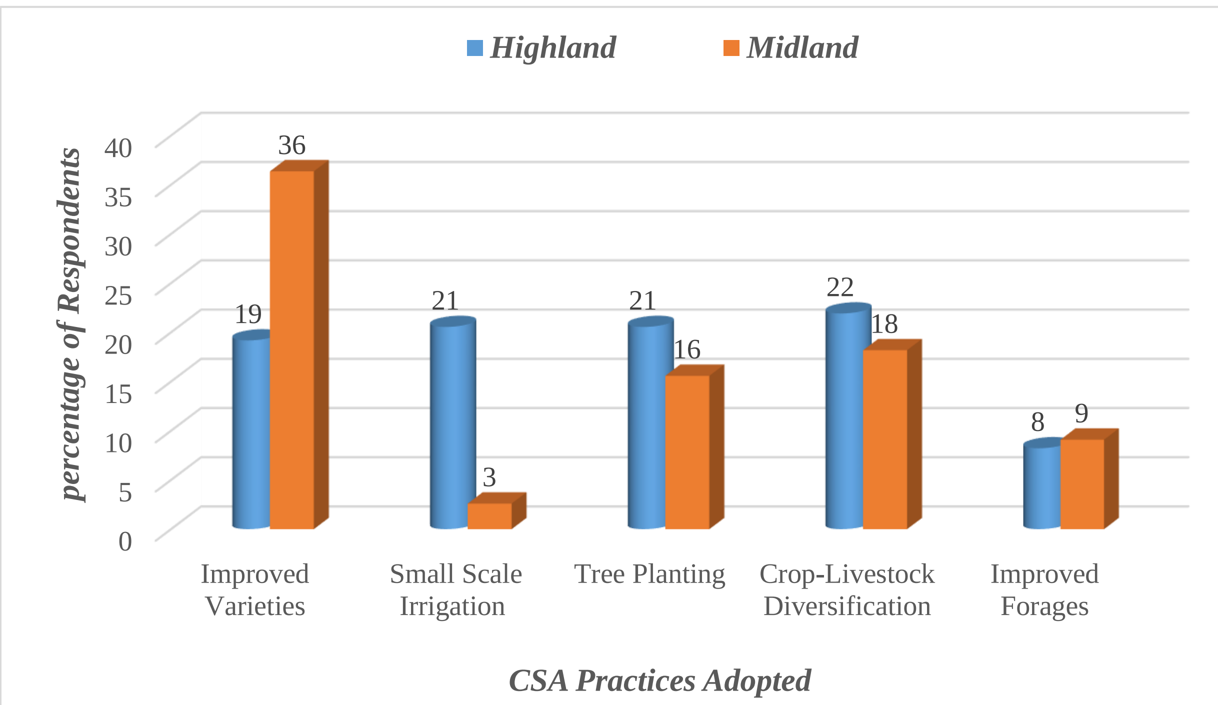


Figure 5.*CSA Practices adopted by HH farmers in Digalu-Tijo District.*

(Source: Own Survey Results, 2019)

4.3. Factors influencing the adoption of climate smart agricultural practices

This section reports the results of factors that influence the adoption of CSA practices using the multinomial logit regression model. Before running the multinomial logit model, using Hausman test and the seemingly unrelated post-estimation procedure (SUEST) to test for the validity of the independence of the irrelevant alternatives (IIA) assumptions. The results of the tests show that both tests failed to reject the null hypothesis of independence of the CSA practices adoptions, suggesting that the multinomial logit (MNL) specification is appropriate to model adoption of CSA practice by smallholder farmers. The likelihood ratio statistics as indicated by Chi-square statistics was highly significant ($p < 0.01$), suggesting that the model is good- fit and has a strong explanatory power (see appendix E). VIF for all variables are less than 10, which indicate all the continuous explanatory variables have no multicollinearity problem shown in appendix A. similarly, there is no problem of heteroscedasticity was found in the model shown in appendix F.

The maximum likelihood method was employed to estimate the parameter estimation of the MNL model and statistically significant variables were identified in order to measure their relative importance on the farmers' decision to use CSA technologies. From the regression result, the value pseudo R-square is 0.3237 which implied that 32.37 % of the model was explained by the included explanatory variables. Thus, the parameter estimates of the MNL model were used to enables the direction of the effect of the independent variables on the dependent (response) variable, whereas estimates represent neither the actual magnitude of change nor the probabilities (Table 7)

The estimated coefficients of the MNL model and their levels of significance as well as the marginal effect results are presented in Table 8. Hence, only those variables in marginal effect to represent the magnitudes of change of probability of the dependent variable are interpreted and discussed further.

Agro ecology

The results of multinomial logit regression indicated that different factors affect adoptions of CSA either significantly positively or negatively (Table 8). Agroecology had a significantly positive effect on the adoption of small-scale irrigation, increased with increasing altitude by 32.5%. This suggests that farmers in higher altitude adopt more small-scale irrigation than those in the altitude due to the presence of larger livestock herd size and availability of water. Similarly, the presence of permanent and intermittent rivers in the highland areas may favor small-scale irrigation. On the other hand, farming in highland zone significantly negative effect on the adoption of improved varieties, decreased with increasing altitude by 15.5%, may be due to presence larger farm size, suitability of soil for cultivation and erratic nature of rainfall in the in midland. This finding in line with the reports of Solomon Addisu *et al*. (2016), Abayneh Amare and Belay Simane (2017) and Kindu Mekonnen *et al*. (2019) on the study conducted in other parts of Ethiopia.

Gender of household head

The results in Table 8 showed that gender had a significantly positive effect on the adoption of, crop- livestock diversification practice by 8.3%. This implies that male headed households are more inclined to adopt CSA technologies and diversify their agricultural activities than female headed households. This is may be related to better access to information, extension services and credit services by male headed households than the female headed households due to freedom of mobility, participation in different meetings and trainings that helps for adoption of CSA practices. Similar findings were reported from elsewhere (Temesgen Deressa *et al*. ,2008; Abrham Belay *et al., 2017;* Getachew Teferi, 2018*).*

Age of household head

The age of the household head had significantly negative effect on the adoption of small-scale irrigation technologies. This implies that the older farmers are less likely to opt for small scale irrigation due to limited capacity to implement or limited access to information. This result in line with Aemro Tazeze *et al*. (2012 who reported that increase in age of household reduces the probability of farmers adopting CSA practices. However, Ajibefun and Fatuase (2011), Kide Gebru (2014) and Malefiya Ebabu (2017) reported the reverse in their study on adoption of CSA practices, because as the age of household head increase, the person expected to more experience in weather forecasting and environmental conditions, as well as a greater accumulation of physical and social capital, which increase the adoption capacity of farmers.

Family size of household head

Family size had significantly a positive influence with the likelihood of adopting improved varieties, small scale irrigation and crop-livestock diversification, and improved forages practices with a rate of 4.5, 5.6, 4.5 and 1.83 % respectively. This is may be related to the need of more labour for adopting new technologies as family members are the main sources of labour in agricultural activities. Similarly, the importance of family size for agricultural activities was reported from elsewhere (Chilot Tizale, 2007; Tagel Gebrehiwot and van der Veen.2013).

Land holding size

Land holding size also had a positive influence with the likelihood of adopting planting trees, diversifying crop with livestock and use of improved forages increases with 4.3, 6.3 and 9.4% respectively. This is may be related to greater wealth, more capitals and resources in agricultural activities while having the large farm size provides the opportunity of adopting multiple CSA technologies. This result is in line with the reports of Mengistu et al. (2012) and Yibekal Tessema et al. (2013).

Farming experience

Farming experience of the household head had significantly positive influence on the likelihood of adopting only improved forages practices (Table 8). As the experience of the household head increases in a number of years, the probability of adopting would result increase in 10.4 %. This is may be associated with better knowledge about feeding livestock a quality fodder and obtain higher milk yield. The longer farming experience is the higher the probability of a farmer adapting to climate variability (Nhemachena and Hassan, 2007).

Education of household head

The result of the study revealed that attending school had significantly positive effect on the likelihoods of adopting improved varieties. It is apparent that educated farmers are more likely to use improved varieties which has a potential to reduce the adverse effect of climate related risks. Education supports the adoption status of improved technologies and enables to easily understand the situations, receive and implement the information on a new technology for their farming activities. Similarly, the positive role of education on adopting agricultural technologies are reported from elsewhere (Hailemariam Teklewold *et al*.,2009; 2013; Farid *et al.*, 2015; Abayneh Amare *and* Belay Simane,2017; Garcia *et al*., 2017).

Livestock ownership (TLU)

The resource endowment of smallholder farmers such as livestock ownership had a significantly positive influence with the likelihood of adopting small-scale irrigation practice. A one TLU increase in the number of livestock, increase the probability of adopting small scale irrigation by 5.2%. In this case, livestock is considered as an asset values for farmers by helping as a source of income in order to purchase improved crop variety and irrigation equipment which is a security against crop failure. This can be attributed to increase wealth and income base of farm households which makes more money available in the households (Gutu Tesso *et al*., 2012; Tagel Gebrehiwot and van der Veen., 2013). This result is also similar with (Kide Gebru, 2014; Malefiya Ebabu, 2017; Demissie Gelashe, 2018; Kindu Mengistu, 2019).

The annual income of the household

The income had significantly positive influence on the adoption of crop-livestock diversification. This implies that the likelihoods of adopting crop-livestock diversification increases with increasing in the amount of income. Indeed, this seems logical as adopt better income open an opportunity of purchasing farm inputs (fertilizer, improved seed, livestock feeder, pesticide). A recent study conducted by Lan *et al*. (2018) noted that the impacts of income on adoption of CSA technologies and practices is a positive correlation with farmers' incomes in farming activities. The same findings were reported from elsewhere (Di Falco *et al*,2011; Kide Gebru,2014; Tagel Alemu,2018).

Access to climate information

Access to climate information also had significantly positive influence with the likelihood of adopting improved varieties and crop-livestock diversification by 23 % and 15% respectively. This implies that getting access to weather-related information enhance the knowledge of smallholder farmers on how to adapt to climate variability related risks so that get prepared before it causes disaster through adopting technologies. The importance of weather information for designing adaptive response was reported (CCAFS, 2015). Similarly, studies in line with this study were reported from elsewhere (Temesgen Deressa, 2014; Gebresilassie Asnake and Girma Mammo, 2016; Amogne Asfaw et al.,2018).

Extension services

Access to extension services had significantly positive influence with the likelihood of adopting Improved varieties, Small scale irrigation, Crop-livestock diversification and Improved forages by 3.1 %, 15%, 16.4% and 14 % respectively. This may be related to the knowledge gained from (training, farm field visit, sharing experience among farmers) as well as access to information and the presence of large farm size and herd size. This implied that those who have trained and engaged in agricultural extensions would have a better opportunity to adopt more CSA technologies required to increase agricultural productions and diversify sources of incomes. A study conducted by Temesgen Deressa *et al*. (2014) reported that providing short-term training and access to information play paramount role in enhancing the adaptive capacity of smallholder farmers. The positive role of extension services on technology adoption were also reported from elsewhere (Shongwe *et al*, 2014; Gebresilassie Asnake and Girma Mammo, 2016; Amogne Asfaw *et al*.,2018; Guush Berhane *et al*.,2018).

Credit services

Access to credit services also had significantly positive influence on the adoption of small-scale irrigation practice. Having access to credit increases the probability of adoption of small-scale irrigation increased by 27 %. This may be explained by the fact that the availability of credit minimizes cash constrains, allows farmers to purchase irrigation facilities and agricultural inputs to enhance adoption of irrigation practice. A study by Gebresilassie Asnake and Girma Mammo (2016) reported that a positive association between access to credit and irrigation practices. The positive role of access to credit services on the technology adoption were also reported from elsewhere (Temesgen Deressa *et al.*,2009; Abrham Belay *et al.,2017*; Tagel Alemu, 2018).

Table 7. Parameter estimates of the multinomial logit model for factors influencing the adoption of CSA practices

Explanatory Variables	**Improved Varieties**		**Small Scale irrigation**		**Tree Planting**		**Crop-livestock diversification**		**Improved Forage**	
	β(coef)	sig (p-value)	β(coef)	p-value	β (coef)	p-value	β (coef)	p-value	β (coef)	p-value
Agro ecology	-2.134	0.190	7.891	**0.000***	-2.894	**0.074***	-2.941	**0.069***	-1.845	0.303
Gender	2.340	**0.065***	3.106	**0.053***	2.178	**0.087***	2.847	**0.033***	2.660	**0.060***
Age	0.162	0.452	-0.533	**0.032***	-0.184	0.392	-0.112	0.601	-0.028	0.901
Family size	0.646	0.202	1.629	**0.040***	0.344	0.497	0.181	0.724	0.226	0.680
Land holding size	3.751	**0.009***	4.916	**0.001***	4.154	**0.004***	4.388	**0.002***	5.268	**0.000***
Farming experience	0.189	**0.086***	-0.091	0.490	-0.066	0.571	-0.134	0.252	-0.280	**0.040***
Education	0.785	**0.021***	0.759	**0.041***	0.660	**0.053***	0.663	**0.053***	0.664	**0.064***
TLU	0.052	0.891	0.971	**0.038***	0.080	0.835	0.206	0.580	0.113	0.794
Income	0.018	**0.037***	0.235	**0.016***	0.015	**0.083***	0.002	**0.019***	0.0012	0.183
climate information	4.085	**0.001***	3.381	**0.028***	2.744	**0.023***	2.178	**0.075***	3.784	**0.008***
Access to extension	2.516	**0.037***	4.652	**0.009***	1.289	0.273	1.988	**0.098***	4.152	**0.009***
Access to credit	2.612	**0.019***	7.059	**0.000***	2.774	**0.016***	2.775	**0.016***	1.893	0.135
Base category					No adaptation					
Number of observations					150					
LR Chi2					167.14					
Log likelihood					-174.575					
Prob > Chi2					0.0000					
Pseudo R2					0.3237					

Keys: *, **, *** = significant at 1%, 5%, and 10% probability level, respectively (source: own survey results,2019)

Table 8. Marginal effects after multinomial logistic regression adoption model

Explanatory Variables	Improved Varieties	Small Scale irrigation	Tree Planting	Crop-livestock diversification	Improved Forages
Agro ecology	-0.1549*	0.3250*	0.0101	-0.025	0.0760
	0.053	0.000	0.888	0.0973	0.184
Gender	-.0134	.0393	-.0291	.0825*	.0182
	0.870	0.538	0.688	0.064	0.738
Age	.0001	-.0240*	.0003	.0105	.0106
	0.992	0.001	0.737	0.269	0.138
Family size	.0449*	.0557*	-.0166	.0499*	.0183*
	0.069	0.013	0.528	0.082	0.033
Land holding size	-.0713	.0461	.0342*	.0630*	.0939*
	0.226	0.125	0.046	0.044	0.017
Farming experience	-.0101	.0028	.0115	.0006	.104*
	0.236	0.614	0.124	0.936	0.084
Education	.0252*	.0041	.0003	-.0006	-.0015
	0.056	0.663	0.975	0.958	0.865
Livestock ownership	-0277	.0518*	-.0167	.0025	-.0047
	0.293	0.002	0.510	0.916	0.0785
Income	0.0027	0.0034	0.0022	0.0058*	-0.0033
	0.515	0.196	0.541	0.079	0.230
Climate information	.2316*	.0194	-.0330	.1484*	.0522
	0.008	0.741	0.613	0.020	0.373
Access to extension	.0310*	.1494*	1641*	-.0670	.1366*
	0.037	0.052	0.010	0.349	0.085
Access to credit	-.0507	.2703*	-0103	-.0252	-.0754
	0.550	0.002	0.890	0.750	0.128

Notes: *, **, *** = significant at 1%, 5%, and 10% probability level, respectively (Source: own survey results,2019)

4.4. Effectiveness of climate smart agricultural practices in the study area

The effectiveness of CSA practices in the study area was evaluated in terms of food security and adaptation indicators. The application of assessing, evaluating and monitoring has the potential to increase the effectiveness of a wide range of CSA practices among farmers at the farm level. Before running the analytic hierarchy process model, using overall consistency ratio (CR) to test for the validity of the internal consistency to represent the efficacy of the AHP for assessing the effectiveness of CSA practices at the farmer level. Accordingly, the overall consistency ratio (CR) value was less than 0.10 for each pillar. The weight for each factor was calculated through a pairwise comparison matrix and the maximum eigenvalues (λ_{max}) of normalized matrix were computed. The consistency ratio for both food security and adaptation indicators are less than (CR< 0.1), which indicates the paired comparison matrix was used in this study have sufficient internal consistency was acceptable for evaluation of the effectiveness of CSA analysis. Therefore, only two CSA pillars (Food security and adaptation) indices selected by local experts and farmers discussed further. For each of these two main outcomes, there are many dimensions and potential indicators that can be measured for example, increased food security may result from changes in availability of food (e.g. Increased yield), accessibility of food (e.g. increased income, access to market), utilization of food (e.g. increased food safety, diet diversity), or stability of access to food. Stability of access also addresses the resilience of the system, as stability depends on resilience.

4.4.1. Importance of indicators in the food security pillar

The results of the study showed that among the four food security pillars of income, food production, consumption and animal production, income was the most preferred indicator with a weight of 0.57 while animal production was the least preferred indicator with the weight if 0.06 (Fig. 6). Food security pillars refer the most important for improving the core aim of CSA strategies. This finding in line with *Shikuku et al*. (2016) who reported that income and yield were deemed the most important CSA indicators by both male and female farmers in Mbeya, Tanzania.

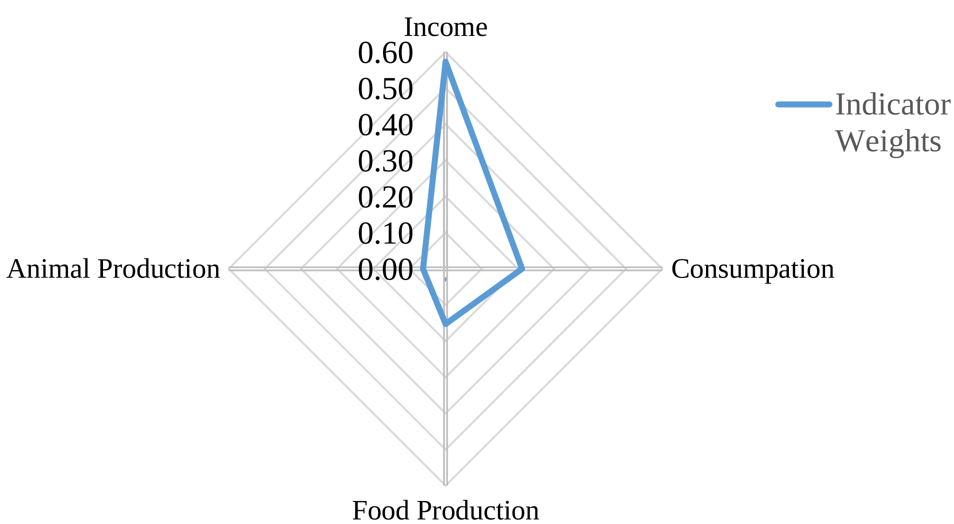


Figure 6. Analytical hierarchical process for food security indicators according to farmers (Source: survey results, 2019)

4.4.2. Importance of indicator in the adaptation pillar

The results showed that among the adaptation pillars, farm productivity, access to information and soil conservation were estimated to be the most important indicators of adaptation with weights of 0.20, 0.18 and 0.14, respectively. This finding agrees with a study conducted by Shikuku *et al*. (2016) and Manda *et al*. (2019) in the uplands and lowlands of Mbarali, Kilolo and lushoto District Tanzania. However, income stability, animal diversity and crop diversity assessed less important by farmers in this pillar, with a weight of 0.05, 0.04 and 0.03, respectively. The results were consistent with the study performed in the Tanzania lushoto district and inconsistent with a study conducted by Cromwell et al (2001) in which crop diversity was deemed most important by farmers in Malawi.

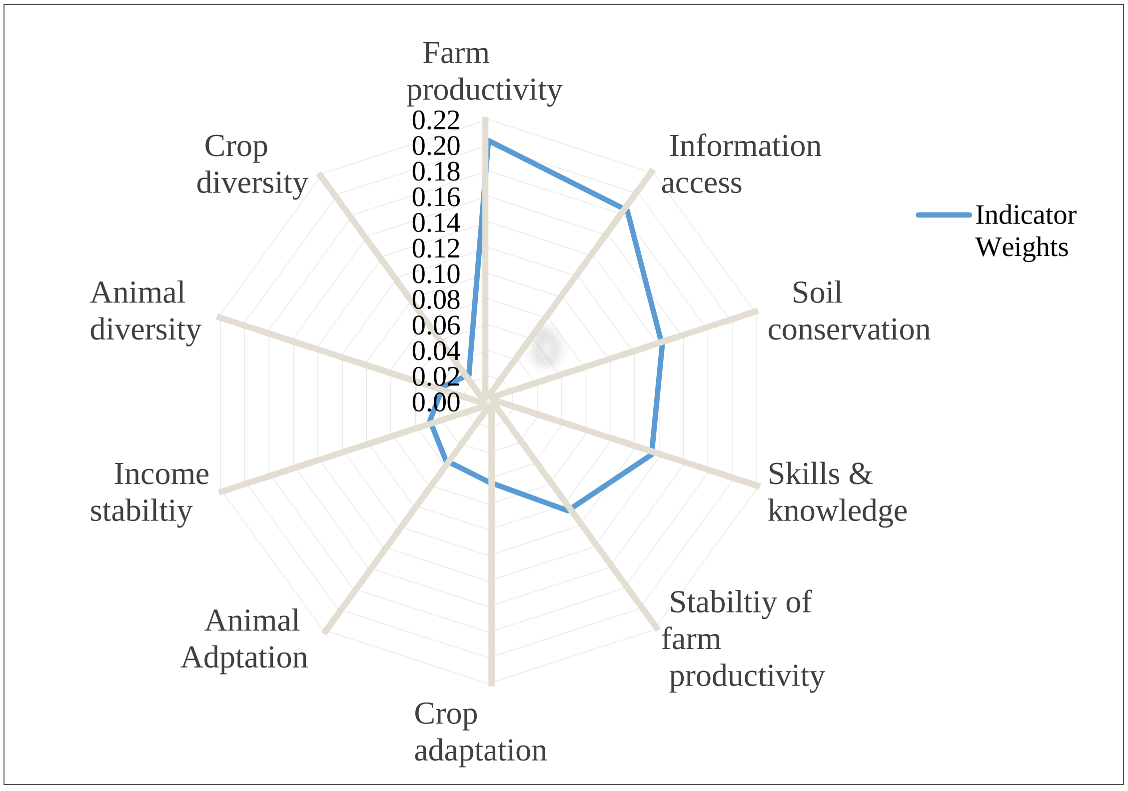


Figure *7*. Analytical hierarchical process for adaptation indicators according to farmers in Digalu-Tijo district (Source: own results, 2019)

4.4.3. Farmer perceptions towards the effectiveness of CSA practices

The result indicated that great majority of the respondents agree or strongly agree that the there has been increase in all the four food security indicators. However, a great majority of them (91% and 88%) agreed or strongly agreed that income (mean score = 4.74) and consumption (mean score = 4.13) had respectively increased since they started adopting the CSA practices (Table 9), Furthermore, relatively smaller proportion of the respondents (61%) perceived that animal productivity (mean score =3.61) has increased since they started using CSA practices. These results are consistent with those of AHP analysis, which revealed that income is the most important indicator in the food security pillar. The least score for animal productivity is also consistent with the results of the evaluation of the CSA practices adoption rate indicated in Fig.6, which is indicated of the least effort made so far in promoting the use of improved forage species among the farmers in the study area. A recent study by Meron Tadesse (2018) reported that farmers perceived CSA is making improvements on crop and livestock productivity, through improved income and diversify livelihood options.

Table 9. Average scores of the food security indicators as indicators of the impact of the CSA intervention in the study area with the use of a Likert scale

Since the start of CSA Practices (N=129)	**SD (1)**	**D (2)**	**N (3)**	**A (4)**	**SA (5)**	**M***	**SD**
Increased income	0	2 1.5%	10 7.8%	35 27%	82 63.6%	4.74	0.682
Increased consumption	0	3 2.3%	12 9.3%	80 62%	34 26.4%	4.13	0.615
Increased food productivity	0	5 3.9%	12 9.3%	72 55.8%	40 31%	4.11	0.739
Increased animal productivity	7 4.7%	12 8%	39 20%	67 44.7%	25 16.7%	3.61	1.009

*Scale Ranges from Strongly Disagree (1) to Strongly Agree (5); M=Mean and SD=Standard deviation (Source: computed from field data, 2019)

In the case of adaptation indicators, the result revealed that great majority of the respondents agree or strongly agree that there has been increase in all the ten adaptation indicators. However, a great majority of them (95% ,94% and 93%) agreed or strongly agreed that information and knowledge (mean score = 4.51), access to information (mean score = 4.06) and farm productivity (Mean=4.03) had respectively increased since they started adopting the CSA practices (Table 10). Furthermore, relatively smaller proportion of the respondents (54% and 42%) perceived that crop diversity (mean score =3.41) and animal diversity (mean score=3.24) has increased since they started using CSA practices. The least score for animal diversity and crop diversity is nearly similar with the results of the evaluation of the CSA practices adoption rate indicated in Fig.7, which is indicated of the least effort made so far in promoting the use of improved forage species and new crop varieties among the farmers in the study area.

Perceived and measures benefits of CSA will encourage farmers to continue practicing CSA technologies. Furthermore, good perception and attitude also motivates peer learning for the adoption of technologies by other farmers (Meron Tadesse,2018). Overall, the perceived level of effectiveness selected climate smart agricultural practices relevant to food security and adaptation indicators as an adaptation option is generally high. This is evident in computed information from the field, experts and other stakeholders at farm level with the top five (improved varieties; small scale irrigation; multipurpose tree planting; crop-livestock diversification and improved forages species) CSA practices and technologies.

Table 10. Average scores of indicators of adaptation as indicators of the impact of the CSA intervention in the study area with the use of a Likert scale

Since the start of CSA Practices (N=129)	SD (1)	D (2)	N (3)	A (4)	SA (5)	M*	SD
Increased access to information	0	3 2.3%	5 4%	93 72%	28 21.7%	4.06	0.647
Increased crop adaptation	0	2 1.5%	6 4.7%	90 69.8%	31 24%	3.83	0.847
Animal adaptation has increased	4 3%	22 17%	34 26.4%	53 41%	16 12.6%	3.41	1.031
Soil conservation increased	5 4%	6 4.7%	22 17%	61 47.3%	35 27%	3.71	1.025
Increased farm productivity	0	4 3%	5 4%	80 62%	40 31%	4.03	0.768
Increased Stability of farm productivity	0	7 5.4%	18 14%	78 60.5%	26 20.1%	3.97	0.789
Income stability has increased	0	4 3%	13 10%	82 63.7%	30 23.3%	4.01	0.714
Animal diversity has increased	2 1.5%	20 15.5%	53 41%	40 31%	14 11%	3.24	0.879
Crop diversity has increased	5 4%	22 17%	33 25.5%	57 44.2%	12 9.3%	3.41	0.991
Increased information & knowledge	0	3 2.3%	4 3%	38 29.7%	84 65%	4.51	0.693

*Scale Ranges from Strongly Disagree (1) to Strongly Agree (5): M=Mean: SD =Standard deviation (source: own survey,2019)

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

From the results of the study, it is concluded that use of improved varieties, small scale irrigation, multipurpose tree planting, crop-livestock diversification and use of improved forages species are the CSA practices being adopted by small holder farmers in the study area. Furthermore, the use of improved varieties in midland agro-ecology and small-scale irrigation in highland agro-ecology were the most widely adopted CSA technologies in the study area.

It was also concluded that the adoption of those CSA technologies was affected by agro ecology, gender, age, education level, family size, landholding size, farming experience, livestock ownership, Annual income, access to climate information, access to extension service and credit services. Several had a positive and significant effect on adoption of the CSA practices. However, age of household has a negative effect on adoption of small-scale irrigation. From this study it can be concluded that the likelihood adoption of CSA practices was observed to be higher with increase the level of education, increase in family size, land holding size, farming experience, number of livestock, access to climate information, access to extension and credit service, increase annual income and younger in age.

From the analysis of the impact of the proxy indicators (indicators of food security and adaptation) it was possible to conclude that the CSA technologies adopted in the study area were effective in that they had positive impact on household income, consumption, food productivity and animal productivity. While farm productivity, access to information, soil conservation, skills and knowledge, soil conservation, stability of farm productivity and crop adaptation were also effective in that they had positive implications as adaptation indicators.

Furthermore, it was also possible to recognize that although they have very high potential in improving livelihood of the farmers, some of the CSA technologies identified during the current study were not promoted very well and therefore were adopted only by small proportion of the farmers in the study area.

5.2. Recommendations

For improving the impacts of CSA practices on the livelihood of farmers and the economy of the nation at large, more CSA technologies should be tested in the area. Furthermore, more concerted efforts by all stakeholders need to be made to promote and make them more accessible to farmers. Accordingly, Lead farmers, research institutions, private sectors, community-based organizations and NGOs should be involved to promote CSA practices and encourage farmers to incorporate all CSAs as much as possible to have a higher effect on agricultural productivity and enable them absorb risks associated with climate risks. In addition to, government should be established climate smart village (CSV) in the area as implementation mechanisms of climate smart agriculture strategies at the farm level and landscape approach to achieve agricultural and environmental sustainability goals.

For instance, planting of multipurpose trees and use of improved forage species should receive better attention in order to have sustainable effect on the livelihood and environment.

6. REFERENCES

Abayneh Amare and Belay Simane. 2017. Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the Upper Blue Nile basin of Ethiopia. *Agriculture & food security 6*(1): 64.

Abayneh Derero.2012. Evaluation of tree seeds and seedling system in Ethiopia with focus in Wolaita and Arsi. *Addis Ababa, Ethiopia*.

Abdollahzadeh, G., Damalas, C.A., Sharifzadeh, M.S. and Ahmadi-Gorgi, H. 2016. Selecting strategies for rice stem borer management using the Analytic Hierarchy Process (AHP). *Crop Protection 84*:27-36.

Abrham Belay, John Recha, Teshale Woldeamanuel and John, F. Morton. 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security* 6(1):24.

Aemro Tazeze, Jema Haji and Mengistu Ketema. 2012. Climate change adaptation strategies of smallholder farmers: the case of Babile district of East Hararghe zone of Oromia regional state of Ethiopia. *Journal of Economics and Sustainable Development* 3(14) : 2222-1700.

Aggarwal, P.K., Jarvis, A., Campbell, B.M., Zougmoré, R.B., Khatri-Chhetri, A., Vermeulen, S., Loboguerrero Rodriguez, A.M., Sebastian, L., Kinyangi, J., Bonilla Findji, O. and Radeny, M. 2018. The climate-smart village approach: framework of an integrative strategy for scaling up adaptation options in agriculture. *Ecology and Society 23*(1: 14).

Amogne Asfaw, Belay Simane, Amare Bantider and Ali Hassen. 2018. Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (Woleka sub-basin). *Environment, Development and Sustainability* :1-31.

Arndt, C. and Tarp, F. 2017. Aid, environment and climate change. *Review of Development Economics 21*(2): 285-303.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A. and Kokwe, M., 2015. Climate smart agriculture? Assessing the adaptation implications in Zambia. *Journal of Agricultural Economics 66*(3):753-780.

Aryal, J.P., Sapkota, T.B., Jat, M.L. and Bishnoi, D.K. 2015. On-farm economic and environmental impact of zero-tillage wheat: a case of north-west India. *Experimental Agriculture 51*(1): 1-16.

Aryal, J.P., Rahut, D.B., Maharjan, S. and Erenstein, O. 2018. Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. In *Natural Resources Forum*. Oxford, UK, Blackwell Publishing Ltd 42(3):141-158.

Assefa Agidew and Singh, K.N. 2019. Assessing Farmers' Perception towards the Effectiveness of Sustainable Land Management Practices in the Teleyayen Sub-Watershed of the Northeastern Highlands of Ethiopia.

Aseres Mamo, Liu, A. and Mwalupaso, G.E. 2019. Adoption of sustainable intensification practices and its effect on smallholders' food security in Ethiopia. *Applied ecology and environmental research 17*(3): 6681-6700.

Asfaw, S., McCarthy, N., Lipper, L., Arslan, A. and Cattaneo, A. 2016. What determines farmers' adaptive capacity? Empirical evidence from Malawi. *Food Security 8*(3):643-664.

Asnake Mekuriaw, Andreas Heinimann, Gete Zeleke and Hurni, H.2018. Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. *International soil and water conservation research* 6(1):23-30.

Gebresilassie Asnake and Girma Mammo. 2016. Farming climate change adaptation mechanisms and factors affecting farmers' decision to adaptation: A case study in Meket district, North Wollo, Ethiopia. *International Journal of Advanced Scientific and Technical Research 6*(2):87–114.

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Wal, T., Soto, I., Gómez-Barbero, M., Barnes, A. and Eory, V. 2017. Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability*

9(8):1339.

Barrios, E., Valencia, V., Jonsson, M., Brauman, A., Hairiah, K., Mortimer, P.E. and Okubo, S. 2018. Contribution of trees to the conservation of biodiversity and ecosystem services in agricultural landscapes. *International Journal of Biodiversity Science, Ecosystem Services & Management 14*(1): 1-16.

Bekele Shiferaw, Menale Kassie, Moti Jaleta and Chilot Yirga. 2014. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy 44*:272-284.

Belaineh Legesse, Yared Ayele and Woldeamlak Bewket.2013. Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research 3*(3):251-265.

Beuchelt, T.D. and Badstue, L. 2013. Gender, nutrition-and climate-smart food production: Opportunities and trade-offs. *Food Security 5*(5):709-721.

Branca, G., McCarthy, N., Lipper, L. and Jolejole, M.C. 2011. Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. *Mitigation of climate change in agriculture series 3*:1-42.

Brüssow, K., Faße, A. and Grote, U. 2018. Adopting climate-smart strategies and their implications for food security.

Central Statistical Authority (CSA). 2013. Summary and statistical report of the 2007. Population and Housing census. Addis Ababa, Ethiopia

Central Statistical Authority (CSA). 2014. Summary and statistical report of the 2007. Population and Housing census. Addis Ababa, Ethiopia.

Challinor, A.J., Watson, J., Lobell, D.B., Howden, S.M., Smith, D.R. and Chhetri, N. 2014. A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change 4*(4) :287p.

Campbell, B.M., Baedeker, T. and Braimoh, A. 2014. Climate-smart agriculture for food security. *Nature climate change 4*(12): 1068p.

Chilot Tizale. 2007. The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia. PhD Thesis. University of Pretoria.

Climate Change and Food Security (CCAFS). 2015. The impact of climate information services in Senegal. CCAFS Outcome Case No. 3. Copenhagen.

Cromwell, E., Kambewa, P., Mwanza, R. and Chirwa, R. 2001. Impact Assessment Using Participatory Approaches:'starter Pack'and S*ustainable Agriculture in Malawi*. OKI, Agricultural Research & Extension Network.

Daniel Asfaw, and Mulugeta Neka. 2017. Factors affecting adoption of soil and water conservation practices: the case of Wereillu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. *International Soil and Water Conservation Research 5*(4):273-279.

Demissie Gelashe .2018. Smallholder Farmers ‘Adoption of Climate Smart Cattle Production Practices: Status and Determinants in Waliso Woreda, Southwest Shoa Zone, Oromia National Regional State, Ethiopia. M.Sc. Thesis. Addis Ababa University.

Di Falco, S., and M. Veronesi. 2013. How African Agriculture Can Adapt to Climate Change? A Counterfactual Analysis from Ethiopia. Land Economics 89(4): 743- 766.

Di Falco. S, Veronesi .M, Mohammed Yesuf .2011. Does adaptation to climate change provide food security Micro perspective from Ethiopia. Am J Agric Econ 93(3):829–846.

Dinesh D, Frid-Nielsen S, Norman J, Mutamba M, Loboguerrero Rodriguez AM, Campbell BM. 2015. Is Climate-Smart Agriculture effective? A review of selected cases. CCAFS Working Paper no. 129. Copenhagen, Denmark: CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS).

Dolan, A.H., Smit, B., Skinner, M.W., Bradshaw, B. and Bryant, C.R.2001. Adaptation to climate change in agriculture: evaluation of options. *Occasional paper*.

Dunnett, A., Shirsath, P.B., Aggarwal, P.K., Thornton, P., Joshi, P.K., Pal, B.D., Khatri-Chhetri,

A. and Ghosh, J. 2018. Multi-objective land use allocation modelling for prioritizing climate-smart agricultural interventions. *Ecological Modelling 381*:23-35.

Elshamy, M., Seierstad, I.A. and Sorteberg, A. 2009. Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios.

Environmental Protection Authority (EPA). 2011. Ethiopia's Climate-Resilient Green Economy (CRGE). *Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia*:188p.

Eshetu Tefera and Cho, Y.B., 2017. Contribution of Small-Scale Irrigation to Households Income and Food Security: Evidence from Ketar Irrigation Scheme, Arsi Zone, Oromiya Region, Ethiopia. *African Journal of Business Management 11*(3):57-68.

Farid, S., Ahmad, R., Niaz, I.A., Arif, M., Shamshir band, S. and Khattak, M.D. 2015. Identification and prioritization of critical issues for the promotion of e-learning in Pakistan. *Computers in Human Behavior 51*:161-171.

Fatuase, A.I. and Ajibefun, A.I. 2011. Determinants of Cassava Farmers 'strategies For Adapting to Climate Change in Ekiti State, Nigeria. *Research Paper* (234).

Feder, G., Just, R.E. and Zilberman, D.1985. Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change 33*(2): 255-298.

Federal Democratic Republic of Ethiopia (FDRE).2011. *Ethiopia's Climate-Resilient Green Economy: Green economy strategy*. Addis Ababa.

Food and Agriculture Organization (FAO). 2018. *Climate-Smart Agriculture Case Studies 2018. Successful approaches from different regions*. Food and Agriculture Organization of the United Nations, Rome. 44 p.

Food and Agriculture Organization (FAO). 2019b. The State of Food Security and Nutrition in the World. Safeguarding against economic slowdowns and downturns. Food and Agriculture Organization of the United Nations. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). 2014. FAO success stories on climate-smart agriculture.

Food and Agriculture Organization of the United Nations (FAO).2016b. Ethiopia Climate-Smart Agriculture Scoping Study. Rome: Food and Agriculture Organization of the United Nations (FAO). Rome. Available at: www.fao.org/3/a-i5518e.pdf.

Food and Agriculture Organization of the United Nations (FAO). 2013. Climate smart agriculture sourcebook. FAO Rome

Food and Agriculture Organization of the United Nations (FAO). 2010.*"Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation.* Report, FAO, Rome. 38 p.

Food and Agriculture Organization of the United Nations (FAO). 2010. Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Rome, FAO.

Food and Agriculture Organization of the United Nations (FAO). 2013. FAOSTAT database. *Food and Agriculture Organization of the United Nations, Rome, Italy, 1*.

Food and Agriculture Organization of the United Nations (FAO). 2017. Climate-smart agriculture sourcebook. Rome, Italy:

Food and Agriculture Organization of the United Nations (FAO). 2016a. State of Food and Agriculture Report "Climate change Agriculture and Food Security" FAO Rome http://www.fao.org/3/a-i6030e.

Garcia, J., da Silva, S.A., Carvalho, A.S. and de Andrade, J.B.S.O. 2017. Education for sustainable development and its role in the promotion of the Sustainable Development Goals. In *Curricula for Sustainability in Higher Education*. Springer, Cham. 1-18 pp.

Getachew Teferi .2018. Climate Variability and Households' Vulnerability to Food Insecurity in Ethiopia. A Case Study of Boset District, East Shewa. PhD Thesis. Addis Ababa University.

Gornall, J, R Betts, and E Burke. 2010. Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions B* 365:2973–2989

Gutu Tesso, Bezabih Emana and Mengistu Ketema. 2012. Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. *Agricultural Sciences 3*(06):871 p.

Greene, W. H. 2018. *Econometric Analysis*. 8th ed. New York: Pearson.

Greene, W.H. 2003. *Econometric analysis*. Pearson Education India.

Gupta, S., Sharma, D. and Gupta, M. 2018. Climate change impact on plant diseases: opinion, trends and mitigation strategies. *Microbes for Climate Resilient Agriculture*:41-56.

Guush Berhane, Catherine Ragasa, Gashaw Tadesse Abate, and Thomas Woldu Assefa. 2018. The state of agricultural extension services in Ethiopia and their contribution to agricultural productivity. *Intl Food Policy Res Inst*.

Hailemariam Teklewold, Alemu Mekonnen, and Kohlin, G. 2019. Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia. *Climate and Development 11*(2):180-192.

Hailemariam Teklewold, Menale Kassie, Bekele Shiferaw and Köhlin, G., 2013. Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor. *Ecological Economics 93*;85-93.

Hailemariam Teklewold, Getachew Legese, Dawit Alemu and Asfaw Negasa. 2009. Determinants of livestock prices in Ethiopian pastoral livestock markets: implications for pastoral marketing strategies. In *Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China*.

Hartmann, D.L., Tank, A.M.K., Rusticucci, M., Alexander, L.V., Brönnimann, S., Charabi, Y.A.R., Dentener, F.J., Dlugokencky, E.J., Easterling, D.R., Kaplan, A. and Soden, B.J., 2013. Observations: atmosphere and surface. In *Climate change 2013 the physical science basis: Working group I contribution to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge University Press:159-254.

Hellin, J. and Fisher, E.2018. Building pathways out of poverty through climate smart agriculture and effective targeting. *Development in Practice 28*(7):974-979.

Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H., 2007. Adapting agriculture to climate change. *Proceedings of the national academy of sciences 104*(50):19691-19696.

Hurni H, Solomon A, Amare Bantider, Berhanu D, Ludi E, Portner B, Birru Y and Gete Z .2010. Land degradation and sustainable land management in the highlands of Ethiopia. In Hurni H, Wiesmann (ed) with an international group of co-editors. G*lobal change and sustainable development: A synthesis of regional experiences from research partnerships. Georaphica Bernensia.* 5. pp.187-201.

Intergovernmental Panel on Climate Change (IPCC).2001). *Climate Change 2001: Synthesis Report*. A Contribution of Working 94 Groups I, II, III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York.

Intergovernmental Panel on Climate Change (IPCC).2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press. Cambridge, United Kingdom and New York, USA. Jury, M.R., 2010. Ethiopian decadal climate variability. Theor. Appl. Climato 101:29–40

Jellis, G.J. 2009. Crop Plant Resistance to Biotic and Abiotic Factors: Combating the Pressures on Production Systems in a Changing World. *Crop Plant Resistance to Biotic and Abiotic Factors: Current Potential and Future Demands,* 15 p.

Kassim Dedefo. 2018.Geomorphologically Instigated Runoff Water and Soil Erosion of Ashebeka Watershed , Digalu Tijo District , Arsi Zone , Oromia . *Journal of Environment and Earth Science* 8(6): 28–39.

Kebede Wolka, Sterk, G., Birhanu Biazin, and Mesele Negash. 2018. Benefits, limitations and sustainability of soil and water conservation structures in Omo-Gibe basin, Southwest Ethiopia. *Land use policy 73* :1-10.

Khatri-Chhetri, A., Aryal, J.P., Sapkota, T.B. and Khurana, R. 2016. Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India.

Khatri-Chhetri, Alemayehu Aggarwal, P.K., Joshi, P.K. and Vyas, S. 2017. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural systems 151*:184-191.

Kidane Georgis Alemneh Dejene and Malo, M. 2010. Agriculturally based livelihood systems in drylands in the context of climate change. *Inventory of adaptation practices and technologies of Ethiopian Institute of Agricultural Research in collaboration with environmental sustainability, 131p*.

Kidane Georgise, Aklilu Negussie, Emiru Birhane, Kiros Meles Hadgu, Badege Bishaw, and Miyuki Iiyama. 2019. Climate Smart Agriculture for Ethiopia and Beyond. *Climate-smart Agriculture*.1:1-13.

Kide Gebru. 2014. Smallholder farmers' adaptation strategies to climate change in Ethiopia: evidence from Adwa Woreda of Tigray Region. M.Sc. Thesis. Mekelle University.

Kindu Mekonnen, Simret Yasabu, Birhanu Gebremedhin, Endalkachew Woldemeskel, Azage Tegegne and Peter Thorne.2019. Promoting productivity and market access technologies and approaches to improve farm income and livelihoods in Ethiopia. In: Lessons from action research projects. *Proceedings of a Workshop, ILRI, Addis Ababa, 8–9 December 2016. Nairobi, Kenya*:1-109.

Kiros Hadgu, Badege Bishaw, Miyuki Iiyama, Emiru Birhane, Aklilu Negussie, Caryn M. Davis, and Bryan Bernart.2019. Climate-Smart Agriculture: Enhancing Resilient Agricultural Systems, Landscapes, and Livelihoods in Ethiopia and Beyond. Editors. World Agroforestry (ICRAF), Nairobi, Kenya.

Korten D. 1980. Community organization and rural development: a learning process approach. Public Administration Review 40(5): 480-511.

Kothari, C. R. 2004. Research Methodology: Methods and Techniques. Second Edition New Age International Limited Publisher, New Delhi.

Lamanna, C., Namoi, N., Kimaro, A.A., Mpanda, M., Egeru, A., Okia, C., Ramírez Villegas, J., Mwongera, C., Ampaire, E.L., van Asten, P.J. and Winowiecki, L.A. 2016. Evidence-based opportunities for out-scaling climate-smart agriculture in East Africa.

Lal, R. 2009. Soils and food sufficiency: A review. In *Sustainable agriculture*. Springer, Dordrecht. 25-49.

Lan, L., Sain, G., Czaplicki, S., Guerten, N., Shikuku, K.M., Grosjean, G. and Läderach, P. 2018. Farm-level and community aggregate economic impacts of adopting climate smart agricultural practices in three mega environments. *PloS one 13*(11):1-21.

Lebacq T, Baret PV, Stilmant D. 2013. Sustainability indicators for livestock farming: a review. Agron Sustain Dev 33:311–327.

Lipper, L. and Zilberman, D. 2018. A short history of the evolution of the climate smart agriculture approach and its Links to climate change and sustainable agriculture debates. In *Climate Smart Agriculture* :13-30.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R. 2014. Climate-smart agriculture for food security. *Nature climate change4*(12):1068p.

Luedeling, E., Smethurst, P.J., Baudron, F., Bayala, J., Huth, N.I., van Noordwijk, M., Ong, C.K., Mulia, R., Lusiana, B., Muthuri, C. and Sinclair, F.L. 2016. Field-scale modeling of tree–crop interactions: Challenges and development needs. *Agricultural Systems 142:*51- 69.

Mano, R. and Nhemachena, C. 2006. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: *A Ricardian approach CEEPA DP11. Pretoria. University of Pretoria*.

Makate, C., Wang, R., Makate, M. and Mango, N.2016. Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change. *Springer Plus 5*(1):1135p.

Makate, C. 2019. Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs. *Environmental science & policy 96*:37-51.

Malefiya Ebabu. 2017. Assessment of Farmers' Climate Information Need and Adoption of Climate Smart Agricultural Practices in Lasta District, North Wollo Zone, Amhara National Regional State, Ethiopia. M.Sc. Thesis. Haramaya University.

Manda, L.T., Notenbaert, A.M. and Groot, J.C. 2019. A Participatory Approach to Assessing the Climate-Smartness of Agricultural Interventions: The Lushoto Case. In *the Climate-Smart Agriculture Papers*. Springer, Cham. pp.163-174

Manda, L.T. 2016. Farm-level Assessment of Climate Smart Agriculture (CSA) Indicators in Lushoto District, Tanzania.M.sc Thesis. Wageningen University and Research Centre.

Mango, N., Makate, C., Lulseged Tamene, Mponela, P. and Ndengu, G., 2018. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land 7*(2):49 p.

Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*, *6*:8-14 pp.

Melaku Jirata, Grey, S. and Kilawe, E. 2016. Ethiopia climate-smart agriculture scoping study. *FAO*.

Menale Kassie, Hailemariam Teklewold, Moti Jaleta, M., Marenya, P. and Erenstein, O. 2015. Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy 42*:400-411.

Mendelsohn, R. 2007. The impact of climate change on livestock management in Africa*: a structural Ricardian analysis*. The World Bank.

Meron Tadesse. 2018. *The implications of climate smart agriculture on soil fertility and productivity: The case of Tula-Jana landscape, SNNPR Region Ethiopia*. MSc Thesis. Addis Ababa University.

Milkesa Tufa. 2018. Indigenous Wisdom and Lore of Weather Forecasting in Oromoo of Ethiopia: A Native Folklore of Arsi Oromo. *Social Science Spectrum*, *3*(4):202-208.

Mittal, S. 2012. Modern ICT for agricultural development and risk management in smallholder agriculture in India. CIMMYT.

Mittal, S. and Bajwa, J. 2018. *Identifying indicators to certify the climate smart villages*. Accessed 16/02.

Moti Jaleta, Menale Kassie, Kindie Tesfaye, Tilaye Teklewold, Jena, P.R., Marenya, P. and Erenstein, O. 2016. Resource saving and productivity enhancing impacts of crop management innovation packages in Ethiopia. *Agricultural Economics 47*(5):513-522.

Mujeyi, K. and Mujeyi, A. 2018. Fostering Climate Smartness in Smallholder Farming Systems: Business Promotional Approaches for Improved Maize Varieties in Eastern and Southern Africa. *Handbook of Climate Change Resilience* :1-24 p

Mulat Gebeyehu, 2016. The impact of technology adoption on agricultural productivity and production risk in Ethiopia: Evidence from Rural Amhara Household Survey. *Open Access Library Journal 3*(02):1 p.

Murage, A. W., Obare, G., Chianu, J., Amudavi, D. M., Midega, C. A. O., Pickett, J. A., and Khan, Z. R.2012. The effectiveness of dissemination pathways on adoption of “Push-Pull” technology in Western Kenya. *Quarterly Journal of International Agriculture* 51(1): 51 – 71.

Mwangi, M. and Kariuki, S. 2015. Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and sustainable development 6*(5):1-10.

National Meteorological Agency (NMA) . 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC).

National Meteorological Agency (NMA). 2007. Climate Change National Adaptation Program of Action (NAPA) of Ethiopia

Neufeldt, H., Jahn, M., Campbell, B.M., Beddington, J.R., DeClerck, F., De Pinto, A., Gulledge, J., Hellin, J., Herrero, M., Jarvis, A. and LeZaks, D. 2013. Beyond climate-smart agriculture: toward safe operating spaces for global food systems. *Agriculture & Food Security 2*(1):12.

Nhemachena, C. and Hassan, R. 2007. *Micro-level analysis of farmers adaption to climate change in Southern Africa*. Intl Food Policy Res Inst.

Notenbaert, A., van de Steeg, J. and Kinyangi, J. 2010. Options for adapting to climate change in livestock-dominated farming systems in the greater horn of Africa. *Journal of Geography and Regional Planning 3*(9):234-239.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J. and Mungai, C. 2017. Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, Northeast Tanzania. *Climate 5*(3):63 p.

Österle, N., Angassa, A., Tadesse, A., Ebro, A., Sauerborn, J. and Treydte, A.C. 2012. Crop-Livestock Farming Systems Varying with Different Altitudes in Southern Ethiopia. *Science, Technology and Arts Research Journal 1*(4):01-13.

Paulos Asrat and Belay Simane. 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, *7*(1):7 p

Quinney, M., Bonilla-Findji, O. and Jarvis, A. 2016. CSA programming and indicator tool: 3 steps for increasing programming effectiveness and outcome tracking of CSA interventions. CCAFS, Copenhagen.

Robinson-Pant, A. 2016. *Learning knowledge and skills for agriculture to improve rural livelihoods*. UNESCO Publishing.

Rosegrant, M.W., Koo, J., Cenacchi, N., Ringler, C., Robertson, R.D., Fisher, M., Cox, C.M., Garrett, K., Perez, N.D. and Sabbagh, P. 2014. *Food security in a world of natural resource scarcity: The role of agricultural technologies*. Intl Food Policy Res Inst.

Rosell, S. 2011. Regional perspective on rainfall change and variability in the central highlands of Ethiopia, 1978–2007. *Applied Geography 31*(1): 329-338.

Roszkowska, E. 2013. Rank ordering criteria weighting methods–a comparative overview.

Rosenstock, T., Lamanna, C., Arslan, A. and Richards, M. 2015. What is the scientific basis for climate-smart agriculture? *Climate Change and Agricultural and Food Security*.

Rosenstock, T.S., Lamanna, C., Chesterman, S., Bell, P., Arslan, A., Richards, M., Rioux, J., Akinleye, A.O., Champalle, C., Cheng, Z. and Corner-Dolloff, C. 2016. The scientific basis of climate-smart agriculture: A systematic review protocol.

Rosenstock, T.S., Lamanna, C., Namoi, N., Arslan, A. and Richards, M. 2019. What Is the Evidence Base for Climate-Smart Agriculture in East and Southern Africa? A Systematic Map. In *the Climate-Smart Agriculture Papers* pringer, Cham. 141-151.

Saaty, T.L. 1980. “The Analytic Hierarchy Process.” McGraw-Hill, New York.

Saaty, T.L., 1988. What is the analytic hierarchy process? In *Mathematical models for decision support*. Springer, Berlin, Heidelberg.:109-121.

Sadiq, M.A., Kuwornu, J.K., Al-Hassan, R.M. and Alhassan, S.I. 2019. Assessing Maize Farmers’ Adaptation Strategies to Climate Change and Variability in Ghana. *Agriculture 9*(5):90p.

Samuel Diro, Efrem Asfaw, Beza Erko and Misganaw Anteneh. 2017. Factors affecting adoption and degree of adoption of soya bean in Ilu-Ababora Zone; Southwestern Ethiopia. *Agricultural Science Research Journal 7*(1):15-26.

Sapkota, T.B., Jat, M.L., Aryal, J.P., Jat, R.K. and Khatri-Chhetri, A. 2015. Climate change adaptation, greenhouse gas mitigation and economic profitability of conservation agriculture: Some examples from cereal systems of Indo-Gangetic Plains. *Journal of Integrative Agriculture 14*(8):1524-1533.

Scherr, S.J., Shames, S. and Friedman, R. 2012. From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security 1*(1):12 p.

Shikuku, K.M., Mwongera, C., Winowiecki, L.A., Twyman, J. and Läderach, P. 2016. Understanding farmers’ indicators in climate-smart agriculture prioritization in the

Southern Agricultural Growth Corridor of Tanzania (SAGCOT).

Shongwe, P., Masuku, M.B. and Manyatsi, A.M.2014. Factors influencing the choice of climate change adaptation strategies by households: A case of Mpolonjeni Area Development Programme (ADP) in Swaziland. *strategies 2*(1).

Sisay Damtie. 2017. Effects of improved livestock feed resources introduced on soil and water conservation Measures by the LIVES Project on livestock productivity and Household income in Debremewi watershed, Yilmana Densa District, Amhara region. M.Sc Thesis., Bahir Dar University Ethiopia.

Smith A, Thorne P, Snapp S .2015. Measuring sustainable intensification in smallholder agroecosystems: a review. Glob Food Secure 12(2017):127–138

Solomon Addisu, Getachew Fissha, Birhanu Gediff and Yemane Asmelash. 2016. Perception and adaptation models of climate change by the rural people of lake Tana Sub-Basin, Ethiopia. *Environmental Systems Research*, *5*(1):7 p.

Solomon Tarfasa, Bedru B. Balana, Tewodros Tefera, Teshale Woldeamanuel, Awdenegest Moges, Mengistu Dinato, and Black, H. 2018. Modeling Smallholder Farmers' Preferences for Soil Management Measures: A Case Study from South Ethiopia. *Ecological Economics 145*:410-419.

Sova, C.A., Grosjean, G., Baedeker, T., Nguyen, T.N., Wallner, M., Nowak, A., Corner-Dolloff, C., Girvetz, E., Laderach, P. and Lizarazo, M. 2018. Bringing the Concept of Climate-Smart Agriculture to Life: Insights from CSA Country Profiles Across Africa, Asia, and Latin America.

Steenwerth, K.L., Hodson, A.K., Bloom, A.J., Carter, M.R., Cattaneo, A., Chartres, C.J., Hatfield, J.L., Henry, K., Hopmans, J.W., Horwath, W.R. and Jenkins, B.M. 2014. Climate-smart agriculture global research agenda: scientific basis for action. *Agriculture & Food Security 3*(1):11p.

Storck, H. and Doppler, W. 1991. *Farming systems and farm management practices of smallholders in the Hararghe Highlands*.

Suleman, K.K.2017. Upscaling Climate-Smart Agriculture in Sub-Saharan Africa.

Tadesse Alemu and Alemayehu Mengistu. 2017. 2. Impacts of Climate Change on Food Security and its Adaptation and Mitigation Options in Ethiopia: A Review. Impact of El Niño on Biodiversity, Agriculture, and Food Security 23-24 February 2017 Haramaya University, Ethiopia :75 p.

Tagel Alemu .2018. Agricultural Technology Adoption, Commercialization and Food Security linkage: Micro Evidence from Boricha Wereda, Sidama Zone snnpr Ethiopia.M.sc Thesis. Addis Ababa University. Ethiopia.

Tagel Gebrehiwot and van der Veen, A. 2013. Farm level adaptation to climate change: the case of farmer's in the Ethiopian Highlands. *Environmental management 52*(1) :29-44.

Taylor, M. 2018. Climate-smart agriculture: what is it good for. *The Journal of Peasant Studies 45*(1):.89-107.

Temesgen Deressa and Mohammed Hassan. 2009. Economic impact of climate change on crop production in Ethiopia: evidence from cross-section measures. *Journal of African economies 18*(4):29-554.

Temesgen Deressa. 2008. Analysis of perception and adaptation to climate change in the Nile Basin of Ethiopia. *Pretoria: Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria*.

Temesgen Deressa.2010. Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies. PhD Thesis. University of Pretoria.

Temesgen Deressa.2014. Climate Change and Growth in Africa: Challenges and the way forward. *The Brookings Institution Africa Growth Initiative*.29-31.

Temesgen Gashaw, Amare Bantider and Hagos G/Silassie.2014. Land Degradation in Ethiopia: Causes, Impacts and Rehabilitation Techniques. *Journal of Environment and Earth Science* 4(9):98-105.

Tesfaye Hailu and Mekonnen Addis. 2015. Prevalence of coccidiosis among indigenous village and exotic poultry in Digalu and Tijo Districts of Arsi Zone, Ethiopia. *Middle East Journal of Scientific Research 23*(8):1580-1584.

Tewodros Beyene. 2018. Adoption of Climate Smart Agricultural Practices: Determinants and Challenges in Gerar Jarso Woreda of Oromia Regional State Ethiopia. MSc Thesis. Addis Ababa University.

Thierfelder, C., Chivenge, P., Mupangwa, W., Rosenstock, T.S., Lamanna, C. and Eyre, J.X. 2017. How climate-smart is conservation agriculture (CA)?–its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. *Food Security 9*(3):537-560.

Thornton, P. K. and Herrero, M. 2015. 'livestock farming systems in sub-Saharan Africa', *Nature Publishing Group*. Nature Publishing Group 5(9):830–836.

Thornton, P.K. and Herrero, M. 2014. Climate change adaptation in mixed crop–livestock systems in developing countries. *Global Food Security 3*(2):99-107.

Thornton, P.K., Rosenstock, T., Förch, W., Lamanna, C., Bell, P., Henderson, B. and Herrero, M. 2018. A qualitative evaluation of CSA options in mixed crop-livestock systems in developing countries. In: Lipper, L., McCarthy, N., Branca, G., Zilberman, D., Solomon Asfaw (Ed.)*, Climate* Smart Agriculture. Springer, Cham. pp. 385-423.

Totin, E., Segnon, A., Schut, M., Affognon, H., Zougmoré, R., Rosenstock, T. and Thornton, P. 2018. Institutional Perspectives of Climate-Smart Agriculture: A Systematic Literature Review. *Sustainability*, *10*(6):1990 p.

United Nations Convention on Climate Change (UNCC). 2015. United Nations Framework Convention on Climate Change. 12 December 2015.

Van Cauwenbergh N, Biala K, Bielders C .2007. SAFE—a hierarchical framework for assessing the sustainability of agricultural systems. Agric Ecosystem Environ 120(4):229–242.

Verchot, L.V., Van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K.V. and Palm, C. 2007. Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and adaptation strategies for global change 12*(5) :901-918.

Westermann, O., Thornton, P.K. and Förchs, W. 2015. Reaching more farmers: innovative approaches to scaling up climate-smart agriculture.

Wilkinson, K., Grant, W.P., Green, L.E., Hunter, S., Jeger, M.J., Lowe, P., Medley, G.F., Mills, P., Phillipson, J., Poppy, G.M. and Waage, J. 2011. Infectious diseases of animals and plants: an interdisciplinary approach p*hilosophical transaction of the royal soicety*.366:1933–1942.

Williams, T.O., Mul, M.L., Cofie, O.O., Kinyangi, J., Zougmoré, R.B., Wamukoya, G., Nyasimi, M., Mapfumo, P., Speranza, C.I., Amwata, D. and Frid-Nielsen, S. 2015. Climate smart agriculture in the African context. Background Paper. Feeding Africa Conference 21–23 Oct 2015.

World Bank. 2010. The Social dimensions of adaptation to climate Change in Ethiopia. Development and Climate Change discussion papers NO.14.Washington, DC.USA.

World Bank. 2013. Policy brief: opportunities and challenges for climate-smart agriculture in Africa (English). Washington DC: World Bank. briefopportunities-and-challenges-for-climate-smart-agriculture-in-Africa.

World Bank.2016. Climate-smart agriculture indicators: world bank group report number 105162 GLB. World Bank, Washington, DC.

World Meteorological Organization (WMO).2019. *WMO Statement on the Status of the Global Climate in 2018*. World Meteorological Organization.

World Bank. 2018.World Development Indicators Ethiopia. World Bank, Washington D.C

Yibekal A Tessema, Chanyalew S Aweke and Getachew S Endris.2013. Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics 1*(1):13.

Yilma Seleshi and Zanke, U. 2004. Recent changes in rainfall and rainy days in Ethiopia. *International journal of climatology 24*(8) :973-983.

Zilberman, D., Zhao, J. and Heiman, A. 2012. Adoption versus adaptation, with emphasis on climate change. Annu. Rev. Resour. Econ.4(1):27-53.

7.APPENDICES

Appendix A: The Variance Inflation Factors for Multinomial Logit Model

```
Variable |       VIF       1/VIF
-------------+----------------------
         age |      4.81    0.207690
  Familysize |      4.28    0.233888
Farmingexp~e |      3.53    0.283214
Landholdsize |      1.56    0.639570
   Education |      1.29    0.777093
      Income |      1.10    0.909137
         TLU |      1.03    0.971378
-------------+----------------------
    Mean VIF |      2.51
```

Appendix B: Correlation test result for category explanatory variables

```
             | Adapta~n    sex     Agroec~y acescl~o acceEt~n access~y
-------------+------------------------------------------------------
Adaptation~n |   1.0000
         sex |   0.1469   1.0000
 Agroecology | -0.1391    -0.0957   1.0000
acesclimat~o |   0.1100   0.0421   -0.0725   1.0000
acceEtension |   0.2058   0.0254   -0.1293   0.1852   1.0000
accesscred~y |   0.0734   0.0311   0.0620   0.0070   0.0254   1.0000
```

Appendix C: Conversion Factors for Tropical Livestock Unit (TLU)

	Animal Category	Tropical Livestock Unit (TLU)
1	Cow and Oxen	1
2	Heifer	0.75
3	Calf	0.25
4	Weaned Calf	0.34
5	Camel	1.25
6	Horse	1.1
7	Donkey (Adult)	0.7
8	Donkey (Young)	0.35
9	Sheep and Goat (Adult)	0.13
10	Sheep and Goat (Young)	0.06
11	Chicken	0.013

Source: storck et al. (1991)

Appendix D: Estimation Result of multinomial logit mode1

```
mlogit Adaptationoption Education Farming experience Landholdsize Familysize age sex
Agroecology TLU Income acesclimaticinfo acceEtension accesscredity, base (0)

Iteration 0:   log likelihood = -258.14571
Iteration 1:   log likelihood = -194.09979
Iteration 2:   log likelihood = -178.76724
Iteration 3:   log likelihood = -174.99682
Iteration 4:   log likelihood = -174.58699
Iteration 5:   log likelihood = -174.57574
Iteration 6:   log likelihood = -174.57572

Multinomial logistic regression                 Number of obs     =        150
                                                LR chi2(60)       =     167.14
                                                Prob > chi2       =     0.0000
Log likelihood = -174.57572                     Pseudo R2         =     0.3237

-----------------------------------------------------------------------------------------------
              Adaptationoption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------------------+---------------------------------------------------------------
No_Adaptation_Strategies       |  (base outcome)
-------------------------------+--------------------------------------------------------------
Improved Varieties             |
                     Education |   .7852388   .3408394     2.30   0.021     .1172059    1.453272
             Farmingexperience | -.1890898   .1180492    -1.60   0.109    -.4204619    .0422823
                  Landholdsize |   3.751054   1.427048     2.63   0.009     .9540909    6.548017
                    Familysize |   .6464756   .5063761     1.28   0.202    -.3460034    1.638954
                           age | -.1622225   .2159163    -0.75   0.452    -.5854105    .2609656
                           sex |   2.340766   1.269553     1.84   0.065    -.1475111    4.829044
                   Agroecology | -2.133483   1.629171    -1.31   0.190    -5.326599    1.059634
                           TLU |   .0520712   .3808699     0.14   0.891    -.6944201    .7985625
                        Income |   .0000183   8.76e-06     2.08   0.037     1.09e-06    .0000354
              acesclimaticinfo |   4.085989   1.256162     3.25   0.001     1.623957    6.548022
                  acceEtension |   2.516427   1.207951     2.08   0.037     .1488865    4.883967
                 accesscredity |   2.612048   1.116053     2.34   0.019     .4246248    4.799471
                         _cons | -7.618852    5.76127    -1.32   0.186    -18.91073     3.67303
-------------------------------+---------------------------------------------------------------
Small_Scale_Irrigation         |
                     Education |   .7595605   .3710956     2.05   0.041     .0322265    1.486894
             Farmingexperience | -.1003906   .1455938    -0.69   0.490    -.3857493     .184968
                  Landholdsize |   4.916798   1.501806     3.27   0.001     1.973312    7.860284
                    Familysize |   1.293768   .6297027     2.05   0.040     .0595737    2.527963
                           age |   -.533169   .2493422    -2.14   0.032    -1.021871   -.0444672
                           sex |   3.106165   1.603146     1.94   0.053    -.0359429    6.248273
                   Agroecology |   7.891757   2.098681     3.76   0.000     -12.0051   -3.778417
                           TLU |   .9716715   .4694035     2.07   0.038     .0516574    1.891685
                        Income |   .0000235   9.79e-06     2.40   0.016     4.34e-06    .0000427
              acesclimaticinfo |   3.381894   1.541455     2.19   0.028     .3606985     6.40309
                  acceEtension |   4.652712   1.780962     2.61   0.009      1.16209    8.143333
                 accesscredity |   7.059873   1.934197     3.65   0.000     3.268917    10.85083
                         _cons | -4.678758   6.564482    -0.71   0.476    -17.54491     8.18739
-------------------------------+--------------------------------------------------------------
Tree_Planting                  |
                     Education |   .6604118   .3416083     1.93   0.053    -.0091282    1.329952
             Farmingexperience | -.0663021   .1170757    -0.57   0.571    -.2957664    .1631621
                  Landholdsize |   4.154266   1.423487     2.92   0.004     1.364282     6.94425
                    Familysize |   .3442463   .5063131     0.68   0.497    -.6481091    1.336602
                           age | -.1846926   .2159708    -0.86   0.392    -.6079876    .2386024
                           sex |     2.1788    1.27401     1.71   0.087    -.3182149    4.675814
                   Agroecology | -2.894655   1.618223    -1.79   0.074    -6.066315    .2770047
                           TLU |   .0807509   .3872826     0.21   0.835    -.6783091    .8398109
                        Income |   .0000153   8.83e-06     1.73   0.083    -2.00e-06    .0000326
              acesclimaticinfo |    2.74429   1.205406     2.28   0.023     .3817379    5.106842
                  acceEtension |   1.289727    1.17661     1.10   0.273    -1.016386    3.595841
```

```
                accesscredity |   2.774409   1.148835     2.41   0.016      .522733    5.026084
                        _cons | -4.598356   5.546329    -0.83   0.407    -15.46896    6.272249
-------------------------------+----------------------------------------------------------------
Crop_livestock_diversification |
                    Education |   .6630694   .3426278     1.94   0.053    -.0084689    1.334608
            Farmingexperience | -.1345372   .1174101    -1.15   0.252    -.3646569    .0955825
                 Landholdsize |   4.388442   1.434999     3.06   0.002     1.575896    7.200989
                   Familysize |   .1812297    .513516     0.35   0.724    -.8252432    1.187703
                          age | -.1122907   .2147178    -0.52   0.601      -.53313    .3085485
                          sex |   2.847888   1.338402     2.13   0.033     .2246687    5.471107
                  Agroecology | -2.941776   1.619423    -1.82   0.069    -6.115786    .2322344
                          TLU |   .2062583   .3731029     0.55   0.580    -.5250099    .9375264
                       Income |   .0000205   8.76e-06     2.34   0.019     3.33e-06    .0000377
             acesclimaticinfo |   2.178936   1.224504     1.78   0.075    -.2210466    4.578919
                 acceEtension |   1.988164   1.200212     1.66   0.098    -.3642082    4.340536
                accesscredity |   2.775489    1.15649     2.40   0.016     .5088102    5.042167
                        _cons | -7.419212   5.674626    -1.31   0.191    -18.54127     3.70285
-------------------------------+----------------------------------------------------------------
Improved_Forage                |
                    Education |   .6640057    .358006     1.85   0.064    -.0376731    1.365684
            Farmingexperience | .2808085   .1365624     2.06   0.040    -.548466    -.013151
                 Landholdsize |   5.268086   1.500167     3.51   0.000     2.327812     8.20836
                   Familysize |   .2267501   .5505263     0.41   0.680    -.8522617    1.305762
                          age | -.0287172   .2312558    -0.12   0.901    -.4819703    .4245358
                          sex |   2.660618   1.417245     1.88   0.060    -.1171319    5.438368
                  Agroecology | -1.845148   1.792578    -1.03   0.303    -5.358537    1.668241
                          TLU |   .1133529   .4334581     0.26   0.794    -.7362093    .9629152
                       Income |   .0000125   9.42e-06     1.33   0.183    -5.92e-06     .000031
             acesclimaticinfo |   3.784901   1.423547     2.66   0.008     .9948004    6.575002
                 acceEtension |   4.152432   1.590107     2.61   0.009      1.03588    7.268983
                accesscredity |   1.893077   1.266293     1.49   0.135     -.588811    4.374965
                        _cons | -12.88115   6.661618    -1.93   0.053    -25.93768    .1753804
------------------------------------------------------------------------------------------------
```

```
Average marginal effects                      Number of obs     =        150
```

```
dy/dx  w.r.t.:  Education  Farmingexperience  Landholdsize  Familysize  age  sex  Agroecology  TLU  Income
acesclimaticinfo
                acceEtension accesscredity
1._predict: Pr (Adaptationoption==No_Adaptation),
2._predict: Pr (Adaptationoption==Improved Varieties)
3._predict: Pr (Adaptationoption==Small_Scale_Irrigation),
4._predict: Pr (Adaptationoption==Tree_Planting),
5._predict: Pr (Adaptationoption==Crop_livestock_diversification)
6._predict: Pr (Adaptationoption==Improved_Forage)
```

```
------------------------------------------------------------------------------
                 |            Delta-method
                 |      dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
Education        | |
               1 | -.0276152   .0123717    -2.23   0.026    -.0518633   -.0033671
               2 |   .0252985   .0132628     1.91   0.056    -.0006961    .0512931
               3 |   .0041717   .0095858     0.44   0.663    -.0146161    .0229594
               4 |   .0003959   .0127712     0.03   0.975    -.0246352     .025427
               5 | -.0006792   .0129344    -0.05   0.958    -.0260302    .0246717
               6 | -.0015717   .0092353    -0.17   0.865    -.0196725    .0165292
-----------------+------------------------------------------------------------
Farmingexperience | |
               1 |   .0055647   .0042605     1.31   0.192    -.0027857    .0139151
               2 |  .0101829   .0085912     1.19   0.236    -.0270214    .0066556
               3 |   .0028831   .0057225     0.50   0.614    -.0083328    .0140989
               4 |   .0115302   .0074959     1.54   0.124    -.0031614    .0262218
               5 |   .0006101   .0076189     0.08   0.936    -.0143227    .0155429
               6 | .0104052    .0060185    -1.73   0.084    -.0222012    .0013908
-----------------+------------------------------------------------------------
Landholdsize     |
               1 | -.1659919    .044486    -3.73   0.000     -.253183   -.0788009
               2 | -.0713972   .0589411    -1.21   0.226    -.1869196    .0441251
               3 |   .0461503   .0301179     1.53   0.125    -.0128797    .1051802
```

	4	.034247	.0465983	0.73	0.046	-.057084	.1255781
	5	.0630898	.0474708	1.33	0.044	-.0299512	.1561309
	6	.093902	.0392405	2.39	0.017	.0169921	.1708119
Familysize							
	1	-.0158457	.0186836	-0.85	0.396	-.052465	.0207735
	2	.0449872	.0297496	1.51	0.069	-.0133208	.1032953
	3	.0557456	.0225382	2.47	0.013	.0115716	.0999195
	4	-.0166299	.0263454	-0.63	0.528	-.068266	.0350063
	5	.0499032	.0287098	1.74	0.082	-.1061734	.006367
	6	.018354	.018257	1.01	0.033	-.0541372	.0174292
age							
	1	.0060229	.0081009	0.74	0.457	-.0098545	.0219003
	2	.0001072	.0111363	0.01	0.992	-.0217195	.021934
	3	-.0240223	.0073817	-3.25	0.001	-.0384902	-.0095543
	4	.0032602	.0097152	-0.34	0.737	-.0223015	.0157812
	5	.0105812	.0095822	1.10	0.269	-.0081995	.029362
	6	.010571	.0071357	1.48	0.138	-.0034147	.0245567
sex							
	1	-.097542	.0451255	-2.16	0.031	-.1859863	-.0090977
	2	-.0134895	.0827377	-0.16	0.870	-.1756524	.1486734
	3	.039368	.0638674	0.62	0.538	-.0858098	.1645458
	4	-.0291787	.0726573	-0.40	0.688	-.1715843	.1132269
	5	.0825793	.0887837	0.93	0.064	-.0914335	.256592
	6	.0182629	.054654	0.33	0.738	-.0888569	.1253828
Agroecology							
	1	.1067854	.0571636	1.87	0.062	-.0052533	.218824
	2	-.1549431	.0800951	1.93	0.053	-.0020405	.3119267
	3	.3250562	.0641874	-5.06	0.000	-.4508611	-.1992512
	4	.0101774	.0724486	0.14	0.888	-.1521741	.1318193
	5	-.0025116	.0744748	-0.03	0.973	-.1484795	.1434564
	6	.0760167	.0571661	1.33	0.184	-.0360268	.1880601
TLU							
	1	-.0051764	.0138412	-0.37	0.708	-.0323047	.0219519
	2	-.0277782	.0264352	-1.05	0.293	-.0795902	.0240339
	3	.0518797	.0170126	3.05	0.002	.0185356	.0852237
	4	-.0167025	.0253371	-0.66	0.510	-.0663622	.0329572
	5	.0025482	.0241732	0.11	0.916	-.0448303	.0499267
	6	-.0047708	.0174535	-0.27	0.785	-.0389791	.0294374
Income							
	1	-0.00631	2.99e-07	-2.31	0.021	-1.28e-06	-1.06e-07
	2	0.00275	4.63e-07	0.65	0.515	-6.06e-07	1.21e-06
	3	0.00341	2.90e-07	1.29	0.196	-1.94e-07	9.44e-07
	4	-0.002297	4.12e-07	-0.61	0.541	-1.06e-06	5.56e-07
	5	0.005836	4.04e-07	1.58	0.079	-1.52e-07	1.43e-06
	6	-0.003383	3.10e-07	-1.20	0.230	-9.79e-07	2.36e-07
acesclimaticinfo							
	1	-.1218874	.038829	-3.14	0.002	-.1979908	-.045784
	2	.2316588	.0872131	2.66	0.008	.0607243	.4025933
	3	.0194556	.0587837	0.33	0.741	-.0957583	.1346695
	4	-.0330583	.0654319	-0.51	0.613	-.1613024	.0951858
	5	.1484049	.0637437	-2.33	0.020	-.2733403	-.0234695
	6	.0522361	.0585873	0.89	0.373	-.0625928	.1670651
acceEtension							
	1	-.085858	.0417107	-2.06	0.040	-.1676094	-.0041066
	2	.0310562	.0844267	0.37	0.037	-.1344171	.1965294
	3	.1494155	.0767639	1.95	0.052	-.001039	.2998699
	4	.1641674	.0638012	2.57	0.010	-.2892155	-.0391193
	5	-.0670985	.0716614	-0.94	0.349	-.2075524	.0733553
	6	.1366523	.0794562	1.72	0.085	-.0190789	.2923835
accesscredity							
	1	-.1084762	.0323987	-3.35	0.001	-.1719766	-.0449759
	2	-.0507223	.0848433	-0.60	0.550	-.2170121	.1155674
	3	.2703148	.0852844	3.17	0.002	.1031605	.4374691
	4	-.0103292	.0748019	-0.14	0.890	-.1569383	.1362799
	5	-.0252947	.0792728	-0.32	0.750	-.1806664	.1300771
	6	-.0754924	.0496424	-1.52	0.128	-.1727898	.021805

Appendix E: Suest Test

```
. suest m1 m2, noomitted

Simultaneous results for m1, m2

                                                Number of obs     =150

. test [m1_Improved_Varieties = m2_Improved_Varieties], cons

 ( 1)  [m1_Improved_Varieties]Education - [m2_Improved_Varieties]o.Education = 0
 ( 2)  [m1_Improved_Varieties]Farmingexperience - [m2_Improved_Varieties]Farmingexperience=0
 ( 3)  [m1_Improved_Varieties]Landholdsize - [m2_Improved_Varieties]o.Landholdsize = 0
 ( 4)  [m1_Improved_Varieties]Familysize - [m2_Improved_Varieties]o.Familysize =0
 ( 5)  [m1_Improved_Varieties]age - [m2_Improved_Varieties]o.age = 0
 ( 6)  [m1_Improved_Varieties]sex - [m2_Improved_Varieties]o.sex = 0
 ( 7)  [m1_Improved_Varieties]Agroecology - [m2_Improved_Varieties]o.Agroecology = 0
 ( 8)  [m1_Improved_Varieties]TLU - [m2_Improved_Varieties]o.TLU = 0
 ( 9)  [m1_Improved_Varieties]Income - [m2_Improved_Varieties]o.Income = 0
 (10)  [m1_Improved_Varieties]acesclimaticinfo - [m2_Improved_Varieties]o.acesclimaticinfo = 0
 (11)  [m1_Improved_Varieties]acceEtension - [m2_Improved_Varieties]o.acceEtension = 0
 (12)  [m1_Improved_Varieties]accesscredity - [m2_Improved_Varieties]o.accesscredity = 0
 (13)  [m1_Improved_Varieties]_cons - [m2_Improved_Varieties]o._cons = 0

           chi2(13) =   23.00
         Prob > chi2 =    0.0416
```

Appendix F. Heteroskedasticity Test

```
: hettest
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of Adaptationoption

         chi2(1)      =     0.01
         Prob > chi2 =   0.9378
```

Appendix G: Questionnaire for Household Survey

Name of The Interviewer: ____

Village Name: ____

CSA Practice Implemented: ____

SECTION- A

PART ONE: GENERAL INFORMATION

1. Agro-ecology :(Dega _______________Wayina Dega_________Kola__________)

2. Zone: _____________ Woreda ___________ Kebele Name__________________

3. Date of Interview ______________________________

PART TWO: HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS

1. Sex of household head: A) Male B) Female

2. Age: _____________ A) 15-24 B) 25-45 C) 45-65 D) 65-80

3. Marital status:

A) Single B) Married C) Divorced) D) Widowed E) Others specify____

4. Family size:

Gender	Age				Total
	<5 yrs.	5 to 15 yrs.	16-65 yrs.	>65 yrs.	
Male					
Female					

5. Educational status:

A) Illiterate B) Read and write C) 10+2 D) other, specify

6. What is the occupation of the household head?

A. Crop farmer B. Livestock Farmer C. Mixed farming, if mixed the dominant one is …………………… D. Others (specify)……………………………………….

7. Do you generate income? A) yes B) No

8 How much income can you generate from your farming activities during last production year (i.e. 2009/2010)? Please specify in Birr

9. How many years have you been in the current farming system?
11. Did any member of the household obtain agricultural credit in the last 12 months? ____ 1= Yes 0=No

12. Where do you feed your cattle? 1 = In stall at homestead 2 = Grazing on paddocks 3 = Grazing on communal land 4= others

13. In case you own cattle, please specify the type and give us some information regarding milk production and marketing in the last and current

Cattle Type	**Season of the year**	**Average milk per animal per day (litres)**	**Amount sold (litres/day)**	**Where milk sold***	**Why this selling option?**	**Price per liter**
Traditional	Dry					
	Wet					
Improved breed	Dry					
	Wet					

16. In case you own crop, please specify the type and give us some information regarding crop production and marketing in the last and current farming system

Crop Type	**Growing season**	**area Average crop per hekt. (quintal)**	**Amount sold (quin/day)**	**Where crop is sold**	**Why this selling option?**	**Price per quintal**
Traditional	Long rains					
	Short rains					
Improved seed	Long rain					
	Short rain					

18. Please can you recall and tell us a land size and a yield obtained from one of a dominantly crop you produced for the last 10years?

19. What constraints did you face in crop production? Please rank them______1. Shortage of rainfall----, 2. Pests and diseases-----, 3. Soil fertility decline------, 4. Lack of farm tools------, 5. Lack of oxen-----, 6. Shortage of land------, 7. Lack of fertilizer and improved seeds-------, 8. soil erosion 9. specify others

SECTION-B

PART TWO: CHARACTIRAZIATION OF LOCAL CLIMATIC PARAMETRES

2.4. What do you think are the causes of the change in the climatic factors you have pointed out in Question above, what are the major problems you faced due to climatic variability?

1.____

2.____

3.____

4.____

SECTION-C

PART THREE: CLIMATE SMART AGRICULTURE

3. Do you know anything about climate smart agriculture?

1= Yes 2= No

A) Are you practicing it? (1, yes 2, not)

B) If yes, what are types of CSA technologies do you in your practice?

____

____

3.1 Climate Smart Agricultural Practices/Technologies and Factors Affecting Adoption of CSA Technologies

3.1.1 Do you grow improved varieties of crop and livestock?

1= Yes 2= No

3.1.2 If your answer to (3.1.1), yes why did you decide to grow improved varieties? ………………………………………………………………………………… ………………………………………………………………………………… …………………………………………………………………………………

3.1.3, Which factor is the most limiting to adopt growing of improved varieties?

3.1.4 Do you adopt tree planting practices on your farm land?
1= Yes 0 = No
3.1.5 If yes in (3.1.4), what attracted you to adopt tree planting practices? ………………………………………………………………………………… ………………………………………………………………………………… …………………………………………………………………………………

3.1.7 If yes, which factor is the most limiting for further adoption of tree planting practices?

3.2 Do you use irrigation for agricultural production? A) Yes B) No

3.2 Do you practice crop-livestock diversification? A) Yes B) No

3.2.1 the factors that hinder the smallholder to adopt implement the crop-livestock diversification technologies

3.2 Do you use adopt improved forages for livestock production? A) Yes B) No

3.2.2 if yes, the factors that hinder the smallholder to adopt implement the introduced climate smart technologies.

PART 5: EFFECTIVENESS OF CSA TECHNOLOGIES DESCRIPTION

A: Pairwise Ranking of The Indicators For Food Security Pillar

Definitions and pair-wise comparison of Analytic Hierarchy Process (AHP) evaluation scale

Intensity of the relative Importance	Definitions
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6 and 8	Intermediate values

Source: Saaty ,1980

Food Security Pillars	income	consumption	Food productivity	Animal productivity
Income	**1**			
Consumption		**1**		
Food Productivity			**1**	
Animal Productivity				**1**
Sum				

B: Pairwise Ranking of The Indicators for Adaptation Pillar

Intensity of the relative Importance	Definitions
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6 and 8	Intermediate values

Adaptation pillar	**information access**	**Crop adaptation**	**Animal Adaptation**	**Soil conservation**	**Farm productivity**	**Stability of farm prodty**	**income stability**	**Animal diversity**	**crop diversity**	**skills & knowledge**
information access	**1**									
Crop adaptation		**1**								
Animal adaptation			**1**							
Soil conservation				**1**						
Farm productivity					**1**					
stability of farm prodty						**1**				
income stability							**1**			
Animal diversity								**1**		
crop diversity									**1**	
skills & knowledge										**1**
Sum										

B**.** The study will use five scores for evaluating how the technologies have had an impact on each of the relevant indicators of the climate smart agriculture; these scores are named as

Selected Climate smart agricultural practices	**1Strongy Disagree**	**2Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly Agree**
2.1 Since you have started using improved varieties income has increased.					
2.2 since you have started using improved varieties consumption has increased					
2.3 Since you have started using improved varieties food productivity has increased.					
2.4 Since you have started using improved varieties your animal production has increased					
2.5 Since you have started using small scale irrigation income has increased					
2.6 Since you have started using small scale irrigation, your skills and knowledge have increased					
2.7 Since you have started using improved varieties access to information has increased					
2.8 since you have started using improved varieties crop adaptation has increased					
2.9 Since you have started using improved varieties animal adaptation has increased					
2.10 Since you have started using small scale irrigation crop diversity has increased					
2.10 Since you have started using improved varieties animal production has increased					
2.11 Since you have started using improved varieties soil conservation has improved					
2.12 Since you have started using improved varieties farm productivity has increased					
2.13 Since you have started using irrigation farm productivity has increased					
2.14 Since you have started using tree planting farm productivity has increased					
2.15 Since you have started using small scale irrigation soil conservation has improved					
2.16 Since you have started tree planting, soil conservation has improved					
2.17 Since you started using tree planting stability of farm productivity has increased					
2.18 Since you started using irrigation household income has increased					

2.19 Using improved forages income has increased.					
2.20 Using small scale irrigation requires more labour.					
2.21 Tree planting requires more labour.					
2.22 Using improved varieties, requires more skills					
2.23 Implementation of small-scale irrigation, requires more skills.					
2.24 Tree planting requires more skills.					
2.25 Using improved varieties, is costly to implement.					
2.26 Using small scale irrigation is costly to implement.					
2.27 Tree planting is costly to implement.					

Checklist for Focus Group Discussions (FGD)

1.What are the climate change events or threats in your area during the last decade? (Explain in terms o, flood, prolonged dry spell, late on set of rains, early cessation of rain, increased seasonal temperature, increased evaporation).

2. What improved practices are popular among farmers? In your estimation, what proportion of participating farmers in the study area has adopted at least one of the improved practices?

3.What do you think are the main reasons for the uptake of these improved practices?

4. As per your knowledge, what are the major determining factors for adoption of the CSA technologies and how did they influence adoption?

5. What benefits do you obtain from the climate smart agricultural practices?

6. How do you see the effectiveness of CSA technologies compared to traditional agricultural practices and other livelihood activities?

Thank you for your time!

Appendix H: Types CSA practices Adopted in Digalu-Tijo district in picture

Figure 13. Improved crop varieties at Digalu Bora kebele (Photo taken in 3/2/2019)

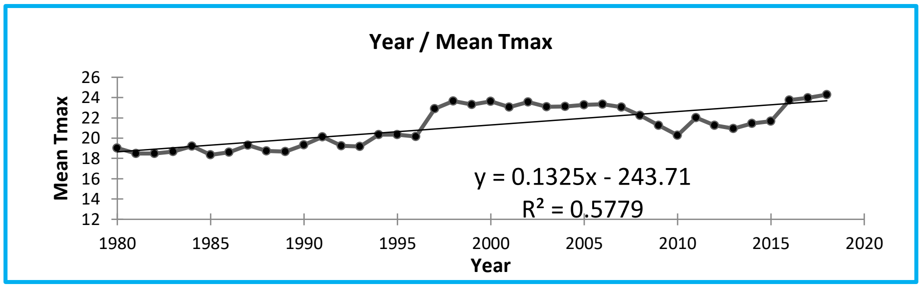
Figure 14. Multipurpose tree species at Digalu Bora kebele (Photo taken in 3/2/2019)

Figure 13. Production of improved Forages species at Shaldo Jigesa kebele (Photo taken in 6/2/2019)

Figure 14. Small Scale Irrigation Practice at Shaldo Jigesa kebele (Photo taken in 6/2/2019)

Appendix. G. Evidence of climatic Parameters

The climatic evidence of the district for the last 38 years characterized by decline in rainfall and increase in temperature



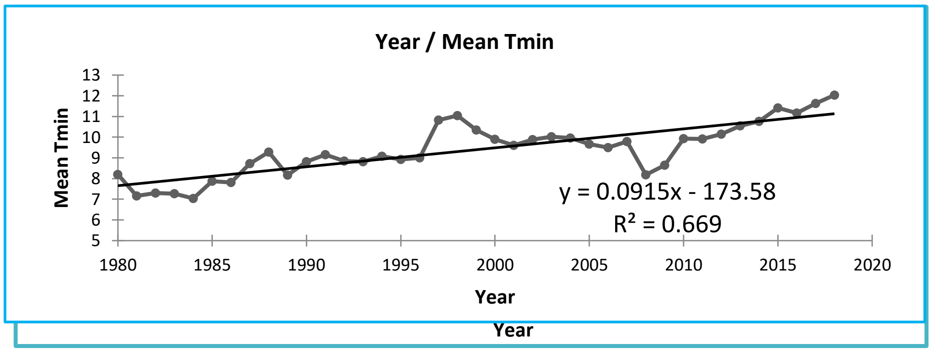


*Figure 4. 1:*Temperature pattern (Mean, Maximum and Minimum) of Digalu-Tijo Woreda (1980–2018) *(source: computed from NMA meteorological data)*

Appendix I: descriptive and Mann Kendall Statistics of temperature trend

Table 10: descriptive and Mann Kendall Statistics for Mean Temperature, Maximum Temperature and annual minimum temperature at Sagure station (1980-2018)

Variables	Tmin	Tmax	Mean Temp
Min	7.0	18.4	12.8
Max	12.0	24.3	18.2
Mean	9.4	21.2	15.3
SD	1.26	1.96	1.53
R2	0.669	0.58	0.68
CV (%)	13.4	9.30	10.00
Sen`s slope	0.09	0.113	0.104
Z value	2.05	0.92	1.84
MK Statics (S)	158	71	142
P -Value	0.0001	0.112	0.111

(Source: Computed from NMA meteorological data)

Table 4. 1: Descriptive statistics of annual and seasonal (FMAM and JJAS) rainfall total of Digalu &Tijo district for 38 years (1980-2018)

	Seasonal rainfall total (mm)		Annual Rainfall Total (mm)
Variables	**Arfaasa (FMAM)**	**Ganna (JJAS)**	
Minimum	**125.2**	**297.8**	**592.6**
Maximum	**692.9**	**784.9**	**1469.8**
Mean	**319.7**	**522**	**940.7**
SD	**128.3**	**117.7**	**198.1**
R^2	**0.18**	**0.03**	**0.184**
CV	**40.1**	**22.6**	**21.06**
Sen`s Slope	**-10.1**	**-5.4**	**-2**
Z value	**-3.2**	**-3.17**	**-0.98**
MK Statics (S)	**-246**	**-253**	**-76**
P -Value	**0.000**	**0.301**	**0.001**

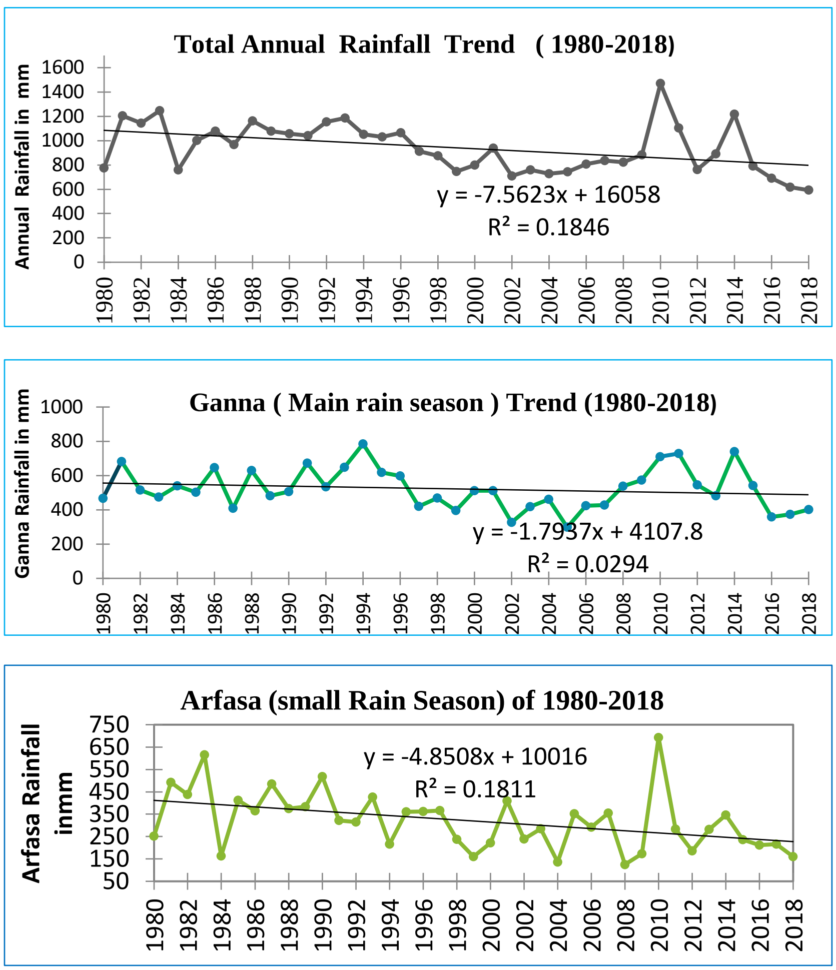


Figure 4. 2:Rainfall Pattern of (Annual, Arfaasa and Ganna) of Digalu-Tijo woreda (1980-2018) (sources: computed from NMA)