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COLLEGE OF DEVELOPMENT STUDIES
CENTER FOR RURAL DEVELOPMENT

CLIMATE CHANGE PERCEPTION, ADOPTION AND DETERMINANTS OF CLIMATE SMART AGRICULTURE PRACTICES IN RESPONSE TO CLIMATE VARIABILITY
THE CASE OF WELMERA WOREDA, OROMIA, ETHIOPIA

M.A. THESIS
MESAY HAILU

AUGUST, 2023
ADDIS ABABA, ETHIOPIA

COLLEGE OF DEVELOPMENT STUDIES
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ADDIS ABABA UNIVERSITY

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR RURAL DEVELOPMENT

DECLARATION

I declare that the thesis work entitled "Climate Change Perception, Adoption, and Determinants of Climate Smart Agriculture the case of Welmera Woreda, Oromia Region, Ethiopia" is my own original research that has not been submitted to another university for a degree or diploma of any kind. I am presenting this thesis work to the Center for Rural Development in partial fulfillment of the requirement for the award of the Master of Art in livelihoods and Rural Development degree. Other people's information and materials are properly acknowledged.

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Date: August 2023

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APPROVAL SHEET

As a major advisor, I have read the thesis by **Mesay Hailu** entitled 'Climate Change Perception, Adoption, and Determinants of Climate Smart Agriculture the Case of Welmera Woreda, Oromia Region, Ethiopia' and endorsed for open defense as part of fulfilling the requirement for the degree of Master of Art in Rural Livelihoods and Development.

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As members of the thesis open defense examining board, certify that we read and evaluated the thesis prepared by Mesay Hailu Gudina entitled, 'Climate Change Perception, Adoption, and Determinants of Climate Smart Agriculture the Case of Welmera Woreda, Oromia Region, Ethiopia' and recommend that the thesis meets the standards for originality and quality and is acceptable for the degree of Master of Art in Rural Livelihoods and Development.

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Final Approval and acceptance of the thesis is determined by the candidate's submission of the final copy of the thesis, combining all of the examining board's feedback and submitting it to the Council of Graduate Studies (CGS) through the Academic Committee (CAC) of the center.

____

Chairperson of the Center or Graduate Program Coordinator

DEDICATION

I dedicate it to my wife and children for their continuous support throughout the study time with their prayers.

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LIST OF ABBREVIATIONS AND ACRONYMS

BFS	Bureau for Food Security
CC	Climate Change
CIAT	International Center for Tropical Agriculture
CSA	Climate Smart Agriculture
CV	Coefficient of variation
DA	Development Agent
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GHG	Green House Gas
HH	Household
IPCC	Inter-Governmental Panel for Climate Change
ILRI	International Livestock Research Institute
IMF	International Monetary Fund
KII	Key informant interview
Km	Kilometer
MK	Mann-Kendal's
MLE	Maximum Likelihood Estimation
MT	Metric Ton
EMA	Ethiopian Meteorology Agency
PCI	Precipitation Concentration Index
SLM	Sustainable Land Management
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
TRA	Theory of Reasoned Action
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nation Development Program
USAID	United States Agency for International Development
UNFCCC	United Nation Framework Convention on Climate Change

ABSTRACT

Climate change is one of the globe's most significant impediments to agricultural productivity and production, with the most devastating consequences in developing countries. As a result, understanding climate change perception and CSA practice adoption level and the influencing elements is critical for policy development and making decisions on CSA practice implementation. The research was conducted in Welmera Woreda, Oromia, Ethiopia. From the Woreda's three kebele, 306 respondent farmers were selected. A cross-sectional survey, focus group discussion and key informant interviews were employed for primary data. A review of related literature was employed for secondary data. Ordered logistic regression and multivariate Probit were employed for analysis of quantitative data. Rainfall and temperature data were analyzed using Mann-Kendall and Sen Slope methods. Qualitative data were analyzed by narration methods. The result indicates 66.6% of the farmers strongly believed that maximum temperatures have been increasing over the last three decades. The result shows 39.8% , 59.5%, and 82.7% of the farmers believed that increased in weed infestation, frequency of livestock illness occurrence and crop disease occurrence. Late onset of main rainy season was perceived by 48.7% the respondents, while 63% perceived early offset of rainfall. 43.8% of all respondents believed that erratic nature of rainfall has increased, and 53.9% believe that water levels are dropping and water sources are disappearing. Conservation agriculture, integrated soil fertility management, and crop diversification are the study areas most extensively used CSA. Based on economic constraint model, having relatively large farmland significantly, increases the adoption of conservation agriculture, improved soil fertility management, diversification of crop, improved livestock feed and feeding practices, and postharvest technology practice. Better farm income increases the uptake of improved livestock feed and feeding. Having a large number of livestock positively influences adoption of conservation agriculture and access credit services has a favorable impact for adoption of agroforestry, crop diversification, and postharvest technology. The innovation diffusion model indicate that access to agricultural extension and training has favorable effects on the adoption of crop diversification; accessibility to participation on farmers' field day similarly influences adoption of conservation practices and improved soil fertility management. The result indicates an unpredictable pattern of rainfall in the study area together with an upward trend in average temperature. Incorporating location-specific CSA practices in to agricultural program and awareness creation for farmers and experts about climate change are essential.

Keywords: Climate change, perception, Climate smart agriculture, Adoption

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Agriculture, as the primary provider and source of food, is the bedrock of human existence. Besides, it contributes significantly to the world economy. 884 million individuals, or 27% of the worldwide labor force, were employed in agriculture in 2019, compared to 40% in 2000 (FAO, 2020). In developing nations, its share of employment is higher than the global average. Agriculture accounts for approximately 50% of total employment in developing countries (Cheong et al., 2013). Unfortunately, climate change disrupts agricultural production, as it is the cause for temperature and precipitation variability. IPCC's Fifth Assessment Report indicated, climate change has reduced global agricultural production by 1–5% in each decade over the last 30 years compared to climate change neutral baseline (Dinesh et al., 2015). Even now, there is a lot of research that shows how common the negative effects of climate change are, such as the extinction of some plant and animal species (FAO, 2016).

Climate change has already had a detrimental effect on agriculture and food security, with these effects being particularly severe in tropical areas where communities heavily depend on agriculture (Lipper & Zilberman, 2018). According to Adesina (2010), the predicted negative impact of climate change is affecting crop output and providing a looming issue for many people, including those in Africa. The disadvantage of climate change, which includes increased pest and disease incidence, threatens Africa's food security (Dinesh et al., 2015). Along with declining agricultural output in some African countries, climate change is likely to drive large regions of marginal agriculture out of cultivation (Boko et al., 2007); consequently, food security is jeopardized and economic development is hampered.

The agriculture, which plays a major role in the country's economy, continues to employ majority of Ethiopians. However, the majority of farmers in the country are smallholders who mainly practice rain-fed and subsistence agriculture. Smallholder farmers produce more than 90% of the agricultural production in the nation (Jirata et al. 2016; Rahel et al. 2021). However, it is awaited that climate change will significantly affect agricultural outputs in Africa, especially Ethiopia (Mekonnen et al., 2021; Rahel et al., 2021). Ethiopian agriculture is mostly rain-fed, therefore it responds to variations in precipitation (Conway and Schipper, 2011). This suggests that crop production may stop being a feasible means of subsistence if rainfall is insufficient in quantity or distribution over multiple growing seasons. This drastic reduction in crop production leads to food insecurity.

Erratic rainfall in some areas, together with severe drought, degradation of land, increase number of population, and climate change, severely constrain the country's economic as well as social advancement, as well as its food security (Jirata et al., 2016). Recurring drought cause food scarcity and affects many people in Ethiopia. Particularly, the droughts of 1984 and 2003, which affected 7.5 and more than 10million people, respectively, had a significant impact on farmers' livelihoods (CIAT; BFS/USAID, 2017). The recent El Nino event in 2015/16 affect the nation with over 10.2 million people believed to require food aid (CIAT; BFS/USAID, 2017). The term "El Nino" refers to the central and eastern tropical Pacific Ocean's warming, which is expected to occur more frequently if current background changes continue under future anthropogenic forcing (Wang et al., 2019).

To overcome the mistrust of agriculture by climate change, emphasis has been given to the creating of means and techniques of keeping up agricultural activities in sub-Saharan Africa (SSA) by encouraging implementation of climate smart agriculture among smallholder farmers by empowering them and increasing their capacity (Branca et al., 2013). Ethiopia also has policies and laws in place to address the effects of climate change on agriculture and the national economy, some of which are relevant to climate-smart agriculture (Eshete et al., 2020).

Various literature and field observations in many areas reveal that adoption of natural resource conservation practices in Ethiopia is low; however, traditional and improved practices are in operation. Despite the fact that Ethiopia carries out a wide range of conventional and cutting-edge agriculture development initiatives as a means of enhancing livelihoods and food security, they are seen also as crucial in resolving climate change-related challenges and are assisting in its adaptation and mitigation (Jirata et al., 2016). CSA is a strategy that calls for location-specific evaluations to determine the most appropriate agricultural production technology and practices to address problems connected to food security, development, and climate change that are intricately intertwined (FAO, 2013). It indicates that, to facilitate the uptake of CSA practices, understanding the farm community ability to adapt and the reaction of institutions requires the integration of the approach into research and development. Furthermore, understanding perception of farmer for climate change risk are crucial since they could influence how farmers embrace CSA practices.

1.2. Statement of the Problem

Climate change is causing droughts to occur everywhere, but their catastrophic effects are more pronounced in underdeveloped nations like Africa (Seleshi & Sanke, 2004). Understanding farmers' views on climate change and the variables influencing their adoption of climate-smart agriculture practices will therefore be crucial for taking action to lessen the effects of climate change.

Sub-Saharan Africa is the part of the world most at risk from climate change (Choi et al., 2020). In sub-Saharan Africa, the impact of climate change is anticipated to reduce the output of major crops drastically, including maize, which is the most significant crop in the area and currently accounts for 13% of cropland area, by 22% in 2050 (FAO, 2012). In the same region, annual grain loss estimates owing to agro-ecosystem degradation are about 6.6 million tons (Munang et al., 2015). According to Zegeye (2018), climate change causes continual droughts and famines, floods, increase in desertification, wetlands degradation, loss of biodiversity, and a shortage of water that causes fall in the agricultural output. Due to this, managing crops and livestock is particularly difficult under the effects of climate change. Climate change is one of the causes of the loss of large numbers of livestock (Chantarat et al., 2014; Kunow, 2016).

Climate change poses serious threats to agriculture, including erratic rainfall, drought, erosion, land degradation, disease outbreaks, yield loss, and livestock loss. Frequent droughts, famines, and starvations are the symptoms indicating the Ethiopia's agriculture is vulnerable to climate change.

To lessen the devastating effects of climate change and variability, integrated management of watershed, combined soil fertility improvement, sustainable use of land, conservation farming, agroforestry, crop residue handling, compost use, implementation of improved livestock feed and feeding and management of rangeland are implementing CSA practices in different areas of the country (Jirata et al., 2016). In Ethiopia, planning for natural resource conservation through large watershed development that comprises tens of thousands of hectares started before three decades; however, low and incomplete adoption owing to the inadequate community involvement and a scant feeling of responsibility over assets (Lakew et al., 2005).

Although it is believed that CSA is location-specific and that its application is worthy of sustained agricultural output, there are few research findings on the factors that influence the adoption of CSA practices for various agro ecologies in Ethiopia, in contrast to other agricultural technology adoption information. For the diverse agro-ecology, soil kinds, weather patterns, agricultural systems, temperatures, and moisture ranges, there is a dearth of adequate and location-specific study findings on practices of CSA in Ethiopia (Jirata, 2016; Wakshum, 2020). Therefore, this study aims to assess farmers' perceptions of climate change, CSA practice adoption, and adoption-influencing factors in the Welmera Woreda, which could help fill a research gap. The study's findings will assist policymakers design location specific CSA practice and establish a strategy because CSA practices adoption reduces the negative effects of climate change while enhancing production.

1.3. Research Objective

1.3.1. General objective

To examine opinion of climate change, adoption, and determinants of climate-smart agriculture practices in the selected kebeles of the district.

1.3.2. Specific objectives

It aims to:

- Investigate the trends in climatic variability (rainfall and temperature) and climate change perception.
- Identify CSA practices that have been adopted in the research area.
- Assess the level of adoption CSA practices.
- Identify factors affecting adoption of CSA practices.

1.4. Research Questions

- What are influencing factors of farmer's climate change perception?
- What are CSA practices carried out in the area in response to climate change effects and what are the levels of adoption?
- What factors significantly determine decision of adoption of CSA practices?

1.5. Significance of the Study

A number of studies on climate-conscious agriculture have been undertaken in Ethiopia. However, only few explored how farmers' perceived climate change influence their decision to use CSA. The study also examines temperature and precipitation trends of the study area. Hence, study focus on how farmers view of detrimental effect of climate change affect perception of climate change. This intern expected to contribute an important working insight for different agricultural stakeholder. In addition, policymakers and other concerned parties can better design development plans and extension systems that helps to minimize the devastating effects of climate change on agriculture.

1.6. Scope of the Study

The scope of the investigation is limited to three kebeles in the Welmera district, west shewa Zone. The purpose of this study is to analyze farmers' perceptions of climate change and determinants of climate smart agriculture adoption. The study collects data through survey, focus groups discussion and interviews with key informants. The study has limitations in terms of extrapolating its findings to a larger geographic area because it only used data from three kebeles in the district.

1.7. Research Limitations

The research was done in the three kebeles, or small geographic areas, of Berfeta Tokofa, Berfeta Lemefa, and Berkusami Gaba Robi because of time and financial restrictions. The investigation is therefore unable to encompass the entire nation's terrain. The study focused solely on production year of 2021/2022

1.8. Ethical Consideration

While honoring the consent of the study subjects, the study carefully evaluated ethical issues. Information is safeguarded in terms of anonymity, honesty, and other human elements. Prior to data collection, after introducing the need for data collection and before the beginning of data collection, respondents' permission was asked. Without the survey participants' approval, no information about the local cultures, names of the respondents, or their individual opinions were gathered and disclosed. To avoid bias, enumerators who were responsible for data collection and questionnaire completion were not residents of the neighborhoods. Along with the aforementioned details, proper monitoring and discussion were carried out during the data collection procedure.

1.9. Organization of the study

This thesis is structured into five chapters. Study background, problem statement, objectives, the study significance, the scope, and limitations of the study are all covered in the first chapter. The second chapter of the thesis addresses a review of the literature. The third chapter provides information about the study area and deals with methodology for the study. The fourth chapter has the findings of the study and its discussion. The final chapter of the study (chapter 5) has a conclusion and recommendation section.

CHAPTER TWO

2. LITERATURE REVIEW

This part of the thesis reviews the literature related to the title of the study. The first part focusses on terms and concept of climate change, climate smart agriculture and related issues. Within the first part, included that adoption theory model focused on three model and the discussion was under sub title 2.1.6.

2.1.Theoretical and Conceptual Literature Review

2.1.1. Climate change

The definition of climate change as the usage of the world meteorological organization relates to changes in the mean long-term weather conditions (FAO, 2008). Such fluctuations can be natural which may happen by significant volcanic eruptions, variations or changes in the sun's activity (Truet et al., 2007). However, since the 1800s, human action, mainly the use of fossil fuels burning, deforestation and raising livestock farming are significantly influencing the earth's temperature due to its potential to add significant amounts of greenhouse gases to those that are already present in the atmosphere and cause global warming (Truet et al., 2007; IPCC, 2022). Climate fluctuation or change has already begun to have a deleterious impact on agriculture and food security. Both climate change and food security get attention, and as an implication of a major finding, supporting smallholders as they adjust to climate change is urgently necessary (FAO, 2016). Therefore, in order to address climate change issue and working to lessen its detrimental effect, it is essential to be aware of farmers' perception and encourage smallholder farmers in poor nations to adopt CSA practices.

2.1.2. Definition and Concepts of Climate Smart Agriculture

Ideas for climate smart agriculture said to be emerging because of climate change and its detrimental effects on the environment and ecology. In 2010, during the Hague Conference on the issues of Agriculture, Food Security, and Climate Change, the Climate-smart agriculture (CSA) was defined and presented by FAO as a strategy for establishing the necessary technical, policy, and financial frameworks to accomplish sustainable agricultural development and provide food security in the face of climate change (FAO, 2013). Consequently, the three aspects of sustainable development (economic, social, and environmental) are integrated within CSA, as defined by the FAO and underpinned by the three main pillars: steadily raising agricultural output and incomes; adapting to and boosting resilience to climate change; and, where feasible, lowering or eliminating greenhouse gas emissions. Lipper et al. (2014) described CSA in line with the recently discovered realities of climate change, as a strategy for restructuring and refocusing development of agriculture.

According to FAO (2013), the population of the globe will rise by 33% from its current level by the year 2050, while the majority living in developing nations. However, the FAO predicted that to fulfill the anticipated food demand by 2050, agricultural production would need to rise by 60%, given the existing pattern of rising income and consumption. As a result, in order to meet the growing need for food, the agriculture industry must transform. However, the detrimental effect of climate change have series impact on agriculture and the ecosystem. Consequently, CSA is a strategy put forth by the FAO to lessen the impact of climate change and maintaining agricultural output (FAO, 2013).

Increasing production while fostering a connection between agriculture and the environment is CSA's top priority. Thus, the basic idea of climate smart agriculture acknowledges the necessity of incorporating the three objectives of climate adaptation, mitigation, and resilience within the structure of sustainable agriculture system (Lipper & Zilberman, 2018). A career in agriculture can assist to lessen the unfavorable effects of climate change and promote the sustainable growth of agricultural production, particularly in developing nations. Because of this, Sullivan et al. (2012) claims that CSA is actively marketed as the future of African agriculture and a practical response to climate change.

2.1.3. Food security

Food security, which is a challenge in poor countries in addition to the climate issue, could exist if agriculture is successful. According to the 1996 World Food Summit, food security is the state when everyone, constantly, have physical and financial access to enough, safe, and nutrient-rich food that satisfies their dietary demands and food choices for functional and healthy existence (FAO, 2016). The definition considers four factors: the availability of adequate amounts and appropriate quality of food, access by individuals to adequate resources (also called entitlements), use of food as well as constancy in food availability and access despite unexpected shocks. However, the four aspects of food security, which are availability, accessibility, use, and system stability, will be severely affected by climate change (FAO, 2008). This implies that both direct and indirect effects of climate change on agriculture productivity and output may be possible. Location-specific CSA techniques are thought to significantly help to reducing the detrimental effects of climate change on food security.

2.1.4. Perception

According to Slegers (2008), Perception described as a range of beliefs, judgments, and attitudes. According to the Concise Oxford Dictionary, it is defined as "a way of regarding, understanding, or interpreting something." In this context, "perception" refers to the farmers' perspective and comprehension of the situation related to climate change and fluctuation. Hence, perception of respondents' about climate change were projected to be distinct from one another. Understanding how farmers feel about climate change is essential for making decisions in line with the uptake of climate smart agriculture practices, hence the study attempts to gather perception and analyze it in relation to numerous factors.

2.1.5. Adoption

Adoption at an individual farmer’s level mean to say that the level of application of a new technology in a long-run equilibrium where a farmer has enough details regarding the new technologies; however, aggregate adoption refers the total number of people who use a specific new technology in a given geographic area or demographic (Feder et al., 1985). Technology acceptance and implementation indicate farmer’s receptivity to use an available new technology into the production process. According to Hall & Khan, (2002), technology adoption is the decision to accept and apply a new product or innovation.

Depending on a variety of variables including personal attitude, adoption may differ from individual to individual and may change over time. Numerous factors can cause people to stop using technology. Individuals may discontinue innovation for three reasons, which include personal, institutional, or social reasons (Dasgupta 1989).

2.1.6. Theoretical Models

The adoption behavior and factors influencing technology adoption are based on three basic theories: the diffusion of innovation, adoption perception, and economic constraints model (Melese 2018). According to innovation diffusion theory, features of innovations that are beneficial to reduce ambiguity surrounding the innovation includes: (1) relative benefit (2) compatibility (3) complexness (4) practicableness and (5) observability. Rogers (2003) asserts that relatively more advantageous, compatible, simple, practicable, and observable innovations will be accepted more quickly as compared with the others.

The main premise of the innovation-diffusion paradigm is that, despite the existence of technically sound and even socially acceptable technologies, the adoption is influenced by the variables that have an impact on how much it costs to find information and how quickly it reaches the appropriate customers (Dissanayake et al. 2022). This theory describes the decision-making process for innovations as activity of seeking the information and processing it., where someone desires to eliminate ambiguity about the benefits and disfavor of an innovation (Sahin, 2006). This implies that information is significantly important for decision in the process of technology adoption. Accordingly, innovation diffusion model, in this study represented by access to extension services & agricultural training, and field day participation.

Adoption perception paradigm assumes farmers hold specific perceptions regarding the change because of innovation or new practices. Farmers will evaluate the technology differently than researchers even when they are fully conscious of all its details (Kivlin and Fliegel, 1967).

The perception of the need to adopt because of the changing situation are depend on qualities of the individual such as education level, experience of an individual and human values of the potential adopters Mudzonga, (2012). Hence, adoption perception theory in this study represented by socio-demographic factors (Abyiot et al., 2023). Study result by Abyiot et al. (2022) indicate that, farmers' attitude of the innovation or technology characteristics, as well as the advantages of CSA practices to food security, climate change adaptation, and mitigation, impacted the uptake of the combination practices of CSA. Thus, I considered perceptions of climate change to be one of the factors influencing the implementation of CSA practices.

The economic constraint model asserts that the economic resources that the person have on hand determine and restrict the decision-making about adoption; accordingly, these resources are labour, land, credit availability and accessibility (Dissanayake et al., 2022). In comparison to using a single paradigm, recent research has revealed that using the three or multiple paradigms to describe technology adoption increases the model's explanatory power (Melese 2018; Dissanayake et al., 2022; Abyiot et al., 2023).

2.2. Review of empirical Findings

2.2.1. Climate change perception

Review of empirical findings focus on farmers' perceptions of climate change and adoption determinants of different climate-smart agriculture practices. Climate change, climate change perception, and implementation of CSA practices are interrelated. Climate change caused by human is the biggest problem in the world and most pervasive challenge to the society and natural environment. Climate change risk perception is perhaps one of the driving forces that motivates farmers to take measure. According to the study by Aimro et al. (2022), the standardized climate change risk perception index indicated that threats associated with potentially hazardous climate change that households in the study region perceive were continual drought, late start of rainfall, early termination of rainfall, and food insecurity. Implementation of CSA techniques by farmers in response to climate change thereby increases productivity, improves resilience to climate change, and lowers greenhouse gas emissions.

Several studies performed by various people shows that various factors influence household perceptions of climatic variability. According to the study by Mudombi (2011), heterogeneity in religion, access to weather information and experiences influences perception of climate

variability-induced hazards. Farmers' perception of climate change was found significantly affected by factors such as age, gender, education, farm experience, irrigation water access, and access to climate change information (Saguye, 2017). Farmers' experiences with events relating to climate such as continual droughts, rainfall reductions, and rainfall delays have an impact on their operations. Other than regional weather changes, perception of climate change can be affected by a number of variables. Infrastructure built to manage or regulate natural resources may influence how people perceive the climate, and similarly, individuals' beliefs about whether or not human activity is to blame for climate change may influence perceptions (Niles & Mueller, 2016).

2.2.2. Climate Smart Agriculture adoption

The objectives of CSA are to: (1) boost agricultural output in a sustainable manner and income; (2) adaptation and build climate change resilience at the local, regional, and country levels; and (3) develop opportunities to lower emissions of greenhouse gases from farming activity (Williams et al., 2015). At the farm level, the intentions and goals of CSA practices are to improve livelihoods and food security, especially for smallholders, through improved natural resource management and usage, as well as the use of suitable methods and technology for agricultural commodity production, processing, and marketing (Williams et al., 2015).

The CSA includes a variety of techniques tied to crop production, animal farming, forestry, and fisheries under the three shared purposes or "pillars" of the CSA. Promising practices and technologies of CSA include cover structures, drip irrigation systems, water harvesting, planting dates adjustment, crop rotation, intercropping, minimum tillage, improved crop varieties, and improved animal breeds, grazing land improvement, hay and silage production, and introducing agroforestry techniques (CIAT; World Bank., 2018).

The pillar of adaptation includes soil health issue, practices of water conservation, diversification and local institutions (Lipper & Zilberman, 2018). In addition to improving crop yield, conservation agricultural practice, which includes reduced tillage, a variety of crop establishment methods, soil nutrient & management of irrigation and residue inclusion can

increase nutrient and water use efficiency, and decrease greenhouse gas emissions from the agricultural fields (Branca et al., 2011; Jat et al., 2014). Increasing the resilience of agricultural production systems to withstand and maintain productivity in the face of extreme events such as drought and climate change is also why CSA should be implemented (FAO, 2013).

Working on sustainable agricultural practices is a wise decision to feed Africa's growing population, especially Ethiopia. Sub-Saharan African imported a total of 18.2 million metric tons (MT) of wheat valued at more than 5 billion dollars during the year 2010, and this increase in wheat consumption is owing to an increase in GDP and population size (Mason et al., 2012). Increasing production and productivity is crucial in this regard.

Adoption of CSA practices is impede by many factors. More specifically, sociodemographic and structural variables, including farmer characteristics, farming practices, and economic circumstances, have a significant impact on whether an invention is adopted (Say et al. 2018). Long-term climatic and landscape-level data are lacking in many African nations (Williams et al., 2015); even if it exist, it is dispersed and difficult to access for use, and among the difficulties are socioeconomic limits at the farm level. Improved technologies and practices to reach the users, accompanying with other factors information plays significant role. Farmers access to information on the types of CSA practices that are best suited to their area is likely to be significant factor for adoption (Kebeda et al., 2019).

According to research on the determinants of CSA practice adoption, get in touch with agricultural extension agents, media exposure, and farming activity are found positively and considerably influence the level of CSA implementation (Abegunde et al., 2019). The decision to implement Climate-smart farming and sustainable land use (SLM-CSA) practices is associated with households that are younger in age, have larger family sizes, and have literate household heads (Beyene et al., 2017).

Credit service is one of the important institutional factors that influences the adoption of agricultural technologies, especially for poor farmers who often have limited financial resources for purchasing agricultural inputs and implements (FAO, 2016).

Farm land size, improved technology inaccessibility, environmental factors, appropriate policy design issue, social expertise, farmers' negative attitudes and motivations, farmers' socio-demographic factors, and farmers' socioeconomic factors are among the factors influencing the adoption of CSA practices (Hailemariam et al., 2019).

2.2.3. Detrimental effects of Climate change on agriculture

Agriculture is a climate-dependent bio-industry. The climate and agriculture have two-way interaction. Agriculture contribution in climate change is significant which includes GHG emissions from synthetic fertilizer (Nitrous Oxide N_2O) use, carbon dioxide (CO_2) from energy use for agriculture, methane (CH4) from substantial increase of livestock production (Aryal, 2022).

Climate change will have an impact on groundwater recharge, the water cycle, soil moisture, livestock, and aquatic creatures. Change in climate raises the prevalence of pests and diseases, which significantly reduces crop output (Kumar et al. 2020). It indicates that the increase in global temperature creates favorable conditions for some pests. Consequently, some pests have already broadened their host or geographic range (Gullino et al., 2022). History has shown that when climatic conditions are especially favorable for disease development, significant crop losses can happen (Burdon and Zhan, 2020).

The livestock sector is one of the agricultural sector that has been negatively impacted by climate change. Disease unquestionably kills 20% of ruminants and more than 50% of chickens annually in developing nations, resulting in a loss of about 300 billion $ annually and study indicates that of the 65 animal diseases that were determined to be the most essential to the poor, 58% are climate-sensitive (Grace et al., 20014).

Water resource impacts of climate change are a top research priority globally (IPCC 2007). Observational data demonstrates the depletion of important water resources, such as lakes and rivers in Ethiopia (Dirirsa, 2019).

Climate change is one the factor that contribute to the nation's water shortage (Hendrix, 2012). In developing nations like Ethiopia, water stress and other climate change-related factors are influencing agricultural production and food security.

For instance, Ethiopia was one of 25 African nations that needed food assistance in 2006 because of ongoing droughts (Dirirsa, 2019).

2.2.4. Potential Benefits of CSA practices

Climate-smart agriculture has recently arisen as a reaction to the need for agricultural system that encourage climate change mitigation and adaptation efforts while improving food security (FAO, 2013; Neufeldt et al., 2013). Site-specific CSA practices benefit users while safeguarding natural resources. It promotes production and incomes while preserving degrading forests, adapting to climate change, and lowering GHG emissions in situations where possible (Nkumulwa and Pauline, 2021).

Study done in Uganda by Zizinga et al., (2022), indicated that compared to the control treatment, CSA practices considerably enhanced total water storage of the soil by 1-12%. This encouraging result supports CSA practices adoption in the area where soil erosion and vegetation loss have reduced food output. Sustainable land management is crucial for preventing land degradation, rehabilitating damaged areas, and ensuring that natural resources are used wisely for current and future generations.

Terrace is a region that has been flattened out on the edge of a hill just for producing crops (The Britannica Dictionary). It minimize the amount and velocity of water traveling across the soil surface, which dramatically reduces soil erosion. Terracing allows for more intensive cropping than would otherwise be possible.

Crop diversification, specifically drought-tolerant, have the potential to withstand the effect of a rise in temperature that could probably affect water availability and crop yields. Drought-tolerant varieties were thought to have a higher densely rooted that level depth in the soil profile, to get and extract soil water (Tesfaye et al., 2018).

Consequently, this makes it easier for plants to get water even in dry conditions, which together with the other factors could raises crop yields.

Weather has a significant impact on yield, growth, and development of agriculture as well as on the prevalence of diseases and pests, the need for fertilizer, and water, and even the quality of produce at the time of transportation services, the viability and vigor of planting material and seeds during storage (Aditya, 2021). Access to weather information, such as temperature and rainfall, aids farmers in planning what to sow when and where.

The promotion of afforestation and replanting as essential climate change mitigation strategies. Because trees absorb atmospheric carbon dioxide (CO_2) through photosynthesis and store it for a long period. Forests and trees safeguard watersheds, support the resilience of farming systems and habitations, support temperature regulation, support the provision of water and shade, protect coastal regions from storms and help regulate climate at the regional and continental scales (Meybeck, 2021). In addition to these benefits, forests play a major role in improving soil organic matter and preventing soil erosion.

2.2.5. Practices of Climate Smart Agriculture and policy implication in Ethiopia

The productivity and resilience of Ethiopia's food systems are put at risk by climate unpredictability and change, which can lead to frequent water stress, droughts, floods, and uneven precipitation (Eshete et al., 2020). Land degradation because of soil erosion and soil fertility reduction are seriously challenging Ethiopian agriculture (Mulugeta, 2004).

Cutting down these effects demand, managing climate risk and long-term adaptation measures (CIAT; BFS/USAID, 2017). Ethiopia developed policies and laws to address the impact of climate change on agriculture and the national economy. It includes the Environmental Policies of Ethiopia, the Environmental Impact Assessment Proclamation, the Sustainable Development and Poverty Reduction Program (SDPRP), strategy for the Development of Community-Based Participatory Watersheds, Ethiopian policy and strategies on conservation, development, and use of forests;

the National Adaptation Program of Action (NAPA), guideline for the updated Community-Based Participatory Watershed Development (Eshete et al., 2020). Numerous international agreements and protocols relating to climate change and degradation of land have been ratified by Ethiopia, including Climate Change Framework Convention of the United Nations (1994), the Convention on Biological Diversity, Convention to Combat Desertification of the United Nations (UNCCD), and the United Nations Sustainable Development Goals (Eshete et el., 2020).

The central point of natural resource and environment policy of Ethiopia is to advance sustainable social and economic advancement via prudent management and utilization of natural, manufactured and cultural resources and the environment as a whole (Lakew, et al., 2005). Rangelands and pastoral systems that are properly managed are climate resilient, profitable, and protect the environment thus, in Ethiopia; different works have been implemented with the aim to strengthen beneficiary communities' livelihoods and the resilience of Ethiopian pastoralists to external shocks, which will help the nation's overall poverty reduction efforts (FAO, 2013).

Conservation agriculture in Ethiopia have been introduced before 16 years, however adoption of the practice is still minimal due to lack of sufficient conservation agriculture integration into the agriculture extension service, open grazing system, lack of alternative energy sources, high cost of input, insufficient access to necessary inputs and equipment and shortage of credit facilities (Jirata et al., 2016). Although Ethiopia has a variety of laws, regulations, and strategies aimed at promoting sustainable development and the mitigation and adaptation to climate change, they are not fully integrated into current projects, programs, and initiatives and lack clear instructions, manuals, and action plans (Jirata et al., 2016).

The term "Climate Smart Agriculture" covers a range of agricultural techniques that aim to increase agricultural production while also utilizing resources efficiently, reducing susceptibility to climate change, and lowering GHG discharge from agriculture (Neufeldt et al., 2013). Management of Integrated watershed, management of integrated soil fertility, sustainable land, conservation agriculture, agroforestry, management of crop residue, compost making, promotion improved livestock feed promotion, and managing rangeland are among the numerous agricultural development practices implementing in Ethiopia that are deemed important in addressing climate change issues (Jirata et al., 2016).

Table 1 Common CSA practices in Ethiopia and its importance (Jirata et al., 2016)

CSA practices	Importance of the practices
Conservation agriculture	• Carbon capture and storage • Lessen current emissions • Ability to withstand dry and hot spells
Comprehensive soil fertility management	• Reduced nitrous oxide and CH4 emission • Increased soil productivity
Small-scale irrigation	• Carbon sink creating • Yields improvement • Strengthened food security
Agroforestry	• Large amounts of CO2 are stored by trees • Improved productivity of agriculture and can support resilience
Crop diversification	• Guaranteeing food security • Resilience to changing weather • Better earnings and alternate careers
Livestock feed and feeding practices improvement	• Livestock productivity improvement • GHG minimization • CH4 minimization
Other practices with components of water harvesting, Systems for early warning and more accurate weather information, alternative energy – (biofuels and fuel efficient stoves), Crop and livestock insurance, Livelihoods diversification and post-harvest innovations (agro-processing, storage)	• Resilience of agriculture • Incomes improved • Emission reduction • Minimize deforestation • Minimize Climate risk

2.3.Conceptual framework

Climate change, one of the world's most pressing issues, has an immediate effect on the availability of water for irrigated crops; similarly, the rise in temperature level and changes in precipitation patterns have a direct impact on crop yield (Nelson et al., 2009).

Location-specific climate smart agriculture believed to lessen the devastating climate change's impact on agriculture. Climate smart agriculture incorporates three objectives of climate adaptation, mitigation, and resilience for sustainable agricultural systems (Lipper & Zilberman, 2018). Thus, assessing farmer's perception of climate change, implementation of CSA practices and identifying factors affecting CSA practices adoption are very important. Even while successful results from properly implemented better practices are anticipated, technology adoption decision, particularly climate-smart agriculture, vary depending on location and time of adoption and may be influenced by a number of factors. Those factors include demographic, socioeconomic and institutional factors (Shifera et al., 2014). Information access, availability of credit and insurance, availability of agricultural input and credit service accessibility are some factors that affect adoption decision of CSA (Kebeda et al., 2019). Implementation of beneficial CSA practices and management practices in less developed nation's obstacle by access to inputs and outputs, as well as financial resource limitations, inadequate infrastructure, and information access. (Collins-Sowan, 2018).

The purpose of this conceptual framework is to indicate that several factors are behind farmer's perception of climate change and adoption decision of CSA practices. This framework of concept is therefore, assembling a variety of elements to obtain a more comprehensive picture since it is important for examining smallholder farmers' perception of climate change and adoption of CSA practices.

In the objective to identify factors affecting farmer's climate change perception, perception of farmers is dependent variables while demographic, socioeconomic and institutional factors are independent factors. In order to assess the relationship, ordered logistic regression model was employed.

Factors affecting CSA practice adoption was examined using multivariate probit model. The probability of adoption of CSA practices in this case is dependent variables while demographic, socioeconomic, institutional variables and farmer's climate change perception level are hypothesized factors affecting adoption of CSA practices.

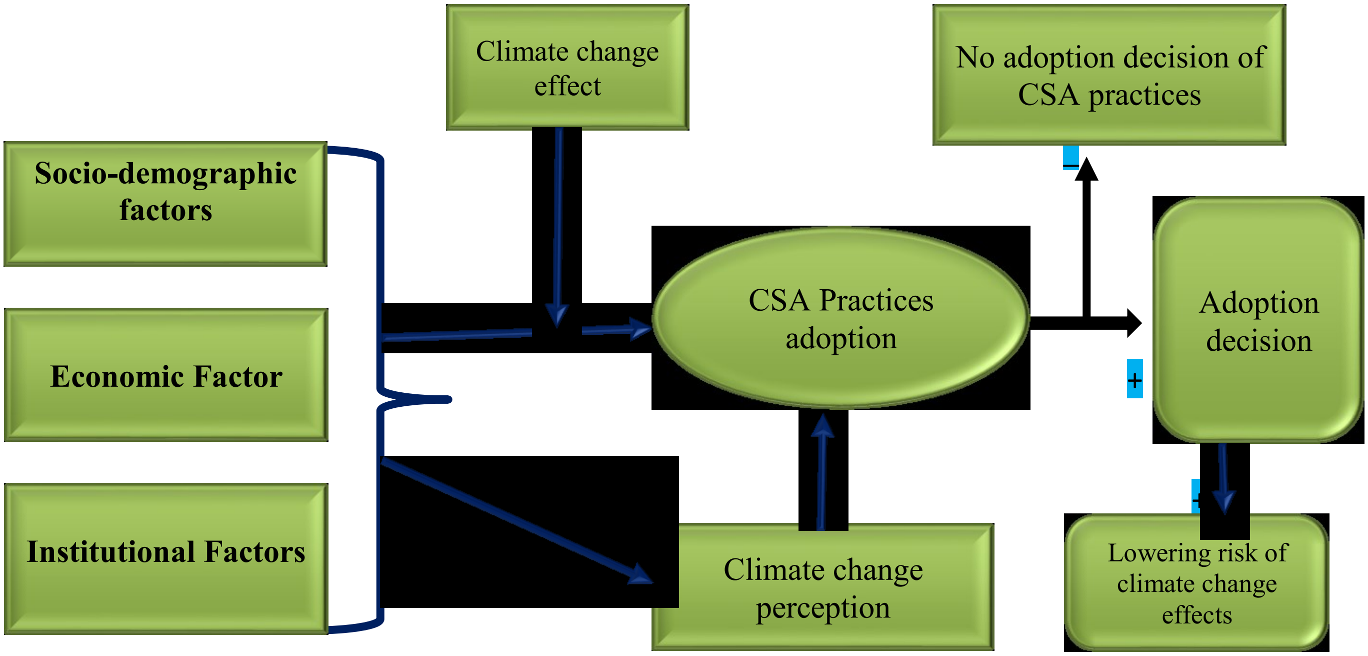

Figure 1: conceptual framework; climate change perception, practices of climate smart agriculture adoption determinants. Source: own illustration

CHAPTER THREE

3. RESEARCH METHODOLOGY

This chapter focus on methods employed to answer all questions of the research. It includes description of the study area, research design and methods employed for data collection. It also clearly elaborate data analysis methods.

3.1. Description of the Study Area

The research was conducted in Welmera woreda Oromia, the woreda is found in West shewa Zone of Oromia region.

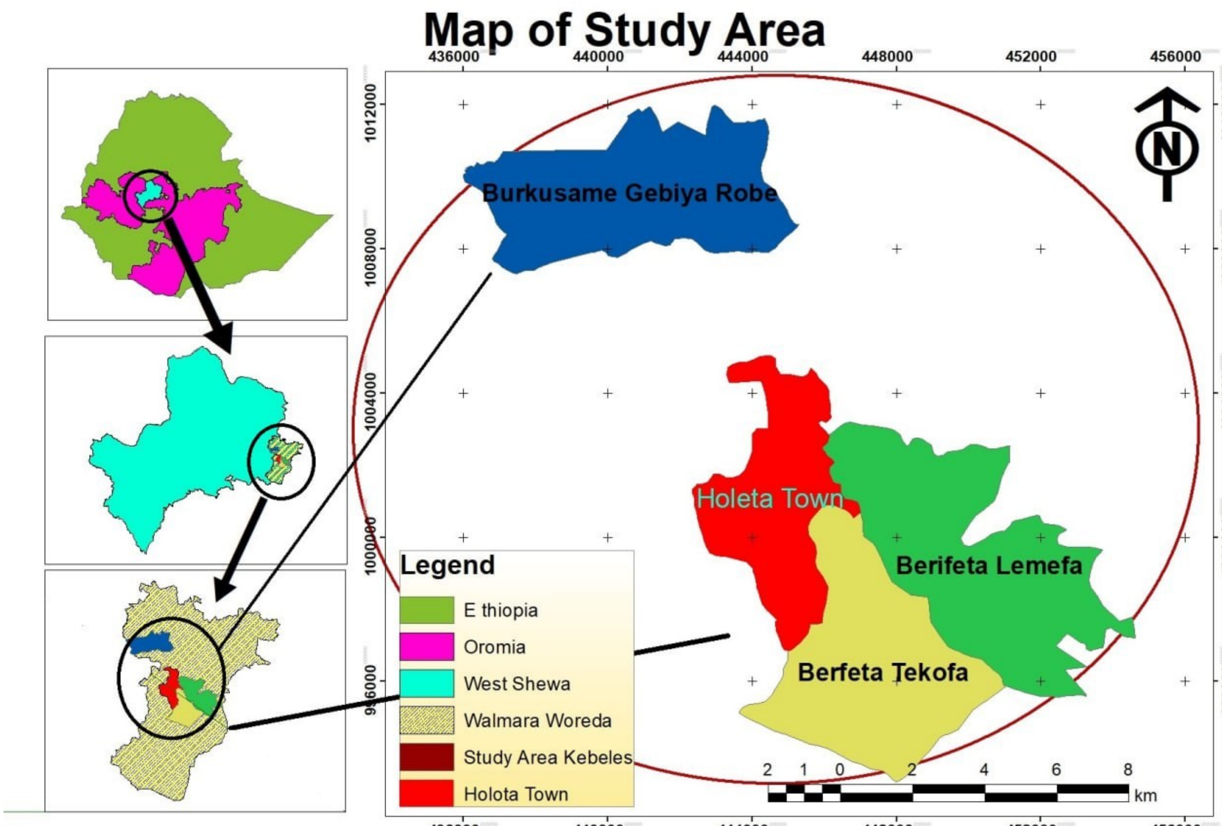

Figure 2: Study kebeles map in Welmera Woreda, Oromia, Ethiopia
Source: Ethiopian Space Science and Geospatial Institute and the Researcher

Location, total land and population

Welmera Woreda is located 29 km. west of the capital Addis Ababa on the main road to Ambo, bordered by Sebeta Hawas woreda, Ejere Woreda, Mulo Woreda, Sululta, and Addis Ababa on the south, on the west, on the north, on the northeast, and on the east, respectively. The district has 26 peasant associations. Its total land area is about 80,927 hectares, of which 37411 hectares are farmland or under cultivation. The altitude of the Woreda ranges from 2060 m a.s.l. to 3380 m a.s.l. The Woreda is located between $8^0 50^{'}$ and 9^0 $15^{'}$ N latitude and $38^0 25^{'}$ and 39^0 $45^{'}$ E longitude. Population size is estimated to be 104,143, with 52,403 men and 51,740 women. (Source: Welmera Woreda Agricultural Office, November 2021).

Climate, Soil and Vegetation

Welmera woreda is divided into two agro-ecological zones: the highland and the midland, based on its altitude. Highland accounts for about 61% of the total, while the midlands approximately 39%. Mean annual rainfall limited between 834 mm and 1300 mm, and the average annual temperature limited between 0 °C and 27 °C. The soil types are red (60%), black (37%), and mixed (3%). The Woreda's primary vegetation types are grazing land and forestland (source: Welmera Woreda Agricultural Office, November 2021).

Economic Activities

The woreda's farmers rely for the most on agriculture for their livelihood. Mixed farming is the most common type of farming in which farmers conduct both crop production and livestock management. Cereals (wheat 29.6%, barley 21.9%, teff 14%, maize 3%), pulses (fava beans 13%, peas 9%, chickpeas 5%), and a small percentage of vegetables and oil crops are grown in the woreda.

In the study area, livestock production also serves as a source of food, energy, and income. There are an estimated 189,861 cattle, 23,750 equines, 110,523 sheep, 15,905 goats, 189,976 chickens, and 356 beehives in the area. (Source: Agricultural Office of Welmera Woreda, November 2021).

3.2. Sampling procedure and Sample size

There was usage of a multistage sampling method during woreda, kebele, and household selection. Purposive sampling methods were employed during Woreda and kebele selection. The woreda was selected purposively based on agricultural production potential. Secondly, three Kebeles those in which there are some startup of CSA practices were selected after discussion made with experts. Finally, respondents are randomly selected. The size of the sample was decided based on Yamane's (1967) sample size formula to get a representative sample (Syed, 2016). The size of the sample from each kebele was decided using the proportional to sample method. Finally, the whole sample size (306 households) was determined based on simple random sampling methods. Long-term rainfall and temperature data for the research area were acquired from the Holeta Agricultural Research Center.

As the unit of analysis, sample households were chosen using a simplified formula developed by Yamane (1967).

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

Where

n= Size of the sample, **N**=population understudy, **e**=error term

The total farm households of the three kebeles are 1308/ sampling frame/ households. Using the aforementioned formula, obtained sample size was 306 households.

$$\boldsymbol{n = \frac{1308}{1+1308(0.05)^2}} = \textbf{306 Households}$$

Table 2 Sample size across the three Kebeles

kebeles	Total household per kebele	Sample proportion	percentage
Berfata Lemefa	272	64	21
Bokusami geba robi	523	122	40
Berfata Tokkofa	513	120	39
Total	1308	306	100

Source: welmera woreda Agriculture office (2022)

3.3. Data sources and Collection tools

3.3.1. Data Sources

This research makes use of secondary data as well as primary data. Household surveys, key informant interview and focus group discussions were used to collect primary data. Secondary data was gathered through reviews of different published and unpublished reports, journal articles, related literature, and reports with related topics of different organization.

3.3.2. Data collection tools

Household survey

Prior to conducting the full survey, the questionnaires for the household survey were developed and tested. Following its testing, the questionnaire was modified in response to feedback and discussions with woreda specialists. Data collection was carried out under the close supervision of the researcher using specially trained enumerators. DAs and some experts from the woreda agriculture office served as the enumerators for data collection.

The household survey questionnaire was designed to collect data on the sample households' demographic and socioeconomic characteristics; farmers' perception of climate change, incidences related to climate change, CSA practice adoption level, and barriers to CSA practice adoption. The questionnaire is also intended to include information about households' access to institutional services and support, which has the potential to affect respondents' decision to implement CSA practices.

Climate change perception parts of the questionnaires consist 12 items (questions), which all positively worded for an assessment of respondents' perception of climate change. The items were created using climatic data and various literary works that were written in response to the detrimental effects of climate change on agriculture.

Key informant Interview

Interview of key informant includes model farmers from kebeles and female-headed households. The interview also includes development agents (DAs), Woreda agriculture experts, and officials from Kebeles. The goal of the interview from key informant was to gather additional in depth qualitative information from participants who were familiar about the study areas. The total number of participants for the key informant interview was planned to be 10; however, saturation point was considered based on the new information accessed from participant individuals or the redundancy of answers from individuals, thus only responses of 7 key informant were used for the key informant interview. The interview guide prepared for key informant interview was consisting 12 guiding questions.

Focus Group Discussion

It is one of qualitative research method and data collection technique when small groups of people discuss on specific topic in depth, with the assistance of experts and external mediator (Eeuwijk and Angehrn, 2017). Three focus group consisted of 8 farmers each group were formed. Groups are homogeneous in terms of sex, age, and experience for a free flowing discussion while feel comfortable with each other. In each kebele, one focus group discussion (FGD), totally three FGDs in the study area. Checklists consisting of nine questions that serve as framework for discussion of FGDs were prepared.

3.4. Analysis of the data

3.4.1. Descriptive and inferential analysis

This section of the study presenting the techniques of analysis and procedures used to analyze gathered data. Data analysis was employed STATA software application. Descriptive analysis as well as econometric tools were employed. Mean, percentage, and frequency are examples of descriptive statistics. Descriptive statistics result and inferential statistics demonstration consists of tables and charts.

There are several models for analysis of factors influencing technology adoption. Probit and Logit are the most commonly used models for quantitative responses. This is because their probabilities are limited between 0 and 1. As a result, the econometric models used to analyze climate change perception and influencing factors of CSA practice adoption are ordered logit and multivariate probit models, respectively. Although there is no compelling reason to prefer one over the other (Logit over Probit or Probit over Logit), many researchers prefer the Logit model due to its relative mathematical simplicity (Gujarati, 2003).

Multivariate probit model is appropriate for analysis of simultaneously implemented multiple practices with binary outcome or response.

Ordered logit model specification

Farmers Adoption of CSA practices may be influenced by their perception on climate change. Farming experience, access to knowledge on climate change, extension visits, training participation, and other relevant factors will all have an impact on farmers' perceptions. For ordered categorical variables in this investigation, the ordered logit model was employed. Although categorical response variables can be modeled using the multinomial logit and probit models, their methodologies are more effective for nominal categorical response variables than ordered categorical response variables (Sainani, 2021; Gujarati, 2003).

Climate change perception: Items included (increased daytime temperatures, increased nighttime temperatures, invasive weed species increase, increased frequency of heat-induced livestock diseases, increased frequency of crop diseases like wheat rust, changed or delayed onset of rainy season, increased frequency of frost season, early secession of rain, increased erratic nature of rainfall, decreasing and disappearance of water sources). The questions were developed in response to observations of the impacts of climate change and fluctuation on agriculture, and they reflect how farmers perceive climate change and variability. To assess respondents' level of climate change perception, they were asked the questions based on a Likert scale response. Perception level categorized in to five; the value was given 1 for very low perception; 2 for low perception; 3 for medium perception; 4 for high perception and 5 for very high perception. The value of farmer's perception to climate change is 1 if climate change perception level is (ccp) < 1.5; 2 if $1.5 \leq ccp < 2.5$; 3 if $2.5 \leq ccp < 3.5$; 4 if $3.5 \leq ccp < 4.5$ and 5 if $ccp \geq 4.5$. Individual farmer perception level is the average response result for all items of a given farmer.

The perception variable is represented as an ordered categorical variable. An ordered Likert scale is used in this study to measure farmer perception. This intern contributes to the analysis of the factors influencing the change from a lower to a higher perception level. To do this, ordered logit model is used.

The latent variable Y* is equal to:

$$\boldsymbol{Y *_i = \sum_{k-1}^{K} \beta_k X_{ki} + \varepsilon_i = Z_i + \varepsilon_i} \text{.......} \mathbf{3.5.1}$$

Where *Zi is:*

$$\boldsymbol{Z_i = \sum_{k-1}^{K} \beta_k X_{ki} = E(Y *_i)} \text{.......} \mathbf{3.5.2}$$

Where

i = 1, 2 , … N is the sample's index of individual respondent, k = 1, 2,...5 is the index of the values of y (1 for very low, 2 for low, 3 for medium, 4 for high, and 5 for very high). xi is the vector of the explanatory variables (demographic, socioeconomic, and institutional), β is the coefficient vector.

Obtained ordinal variable Y is a function of Y*, which is an unmeasured continuous latent variable. Y* has various boundary points k-1. (k=Kappa which is the Greek small letter) value on the observed variable Y depends on whether or not you crossed a particular threshold (Williams, 2022).

Since there are five (5) categories, climate change perception level, perception level of respondents will fall in one of the fifth (5^{th}).

$$P(Y_i = M) = \frac{\exp(X_i\beta - K_{M-1})}{1+[\exp(X_i\beta - K_{M-1})]} \text{.......} \mathbf{3.5.3}$$

Where;

M and k are awareness level and a particular threshold 5-1(4 cuts) in which the value of Y respectively, *Xi* an explanatory variable that influences respondents' perception level, β is unknown estimated parameters.

Ordinal Logit model for analysis of factors influencing farmers' perception of climate change represented as:

$$Yi = \beta o + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots\ldots\ldots . \beta nXn + \mu i \text{.......} \mathbf{3.5.4}$$

Where

Y is dependent variable (the observed ordinal climate change perception), *Xi*................ *Xn* indicates explanatory factors, *β1*............*βn* parameters of explanatory factors, βo and μi displayes the intercept and error term respectively.

For example, when M = 5, the probability of the farmers' perception level fall in one of the five levels is calculated as follows;

$$P(Y=1)=\frac{1}{1+\exp(Z_i-K_1)}\ \ldots\ldots \mathbf{3.5.5}$$

$$P(Y=2)=\frac{1}{1+\exp(Z_i-K_2)}-\frac{1}{1+\exp(Z_i-K_1)}\ \ldots\ldots \mathbf{3.5.6}$$

$$P(Y=3)=\frac{1}{1+\exp(Z_i-K_3)}-\frac{1}{1+\exp(Z_i-K_2)}\ \ldots\ldots \mathbf{3.5.7}$$

$$P(Y=4)=\frac{1}{1+\exp(Z_i-K_4)}-\frac{1}{1+\exp(Z_i-K_3)}\ \ldots\ldots \mathbf{3.5.8}$$

$$P(Y=5)=1-\frac{1}{1+\exp(Z_i-K_4)}\ \ldots\ldots \mathbf{3.5.9}$$

Where the five level of respondents' climate change perception is;

Yi = 1 if $Y^*_i \leq$ k1⇒Very Low Perception Level for Climate change

Yi = 2 if k1 $\leq Y^*_i \leq$ k2⇒ Low Perception Level for Climate change

Yi = 3 if k2$\leq Y^*_i \leq$ k3⇒ Medium Perception Level for Climate change

Yi = 4 if k3$\leq Y^*_i \leq$ k4⇒ High Perception Level for Climate change

Yi = 5 if $Y^*_i \geq$ k4⇒ Very High Perception Level for Climate change

For all possible outcomes to be positive, we have to have k1 < k2 < k3< k4< k5.

Multivariate probit model

The model multivariate probit is a generalization of the probit model utilized to estimate a number of correlated binary outcomes together.

The farmer makes the decision to adopt K^{TH} technology of CSA when

$Y^*_{kj} = U^*_k - U_0 > 0$.

Where U_k = benefit from one of the CSA practices.

U_0 = benefit from traditional or unimproved practices

The farmers net gain (Y^*_{kj}) as a result of K^{th} CSA practice is a latent variable that is influenced by observed sociodemographic, institutional, economic factors and climate change perception level (X_{kj}) and unobserved characteristics (U_{kj}):

$Y^*_{kj} = \beta_k x'_{kj} + U_{kj}$, where (k = CA, ISF, SSI, AF, CD, ILF, IWI, PH)………………**3.5.10**

Translate the unobserved preference in the above equation (equation 3.5.10) into the observed binary output formula for each option of the CSA practices as follows:

$$Y_{kj} = \begin{cases} 1\ if\ \ Y^*_{kj} > 0 \\ 0\ otherwise \end{cases} \quad (k = CA, ISF, SSI, AF, CD, ILF, IWI, PH) \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{3.5.11}$$

Where CA=conservation agriculture, ISF= management of improved soil fertility, SSI=irrigation on small-scale, AF=Agroforestry, CD= cultivating diversified crop, ILF= Improved feed and feeding for livestock, IWI=improved weather information, and PH=Post-harvest technology.

k=1, 2,3, ……m indicates the types of CSA practices, and j=1….n implies sample size.

Initially in the equation (3.5.10), the premise is that a reasonable jth farmer has a latent variable Y^*_{kj} which capture the unobserved characteristics connected the *k*th choice of CSA practice. It is presumed that this latent variable is a linear combination of observed characteristics $\boldsymbol{x'}_{kj}$, factors that influence the implementation of *k*th CSA practice, as well as unobserved characteristics captured by the stochastic error term $\mathbf{U_{kj}}$. The vector of the parameters to be estimated in this model is indicated by $\boldsymbol{\beta_k}$. Given the latent nature of Y^*_{kj}, the estimations are based on binary discrete variables Y_{kj} that can be observed and which pointing whether a farmer adopt or not a particular CSA practices on his/her farm land. If a farmers decision to implement one CSA practice is unrelated to whether or not they implement another practices, and if error terms are normally spread, in that case, equations (3.5.10) and (3.5.11) designate or indicate univariate probit models, where information on farmers' implementation of a single CSA practice does not cause to change the forecast of the likelihood that they will implement another CSA practice. In the case when several CSA practices adoption is possible, a more reasonable specification would be to assume that, the (3.5.10) equation's error terms are jointly follow a multivariate normal (MVN) distribution, with zero conditional mean and variance normalized to unity, $\mathbf{U_{kj}} \sim$ MVN (0, Ω). This indicates that in the multivariate model, when implementation of a number of practices is possible, the error terms jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity, suppose the CSA practices are CA, ISF, SSI, AF, CD, ILF, IWI AND PH, then (μ_{CA}, μ_{ISF}, μ_{SSI}, μ_{AF}, μ_{CD}, μ_{ILF}, μ_{IWI}, μ_{PH}) ~ **MVP** (0, Ω) and the similar size [8x8] covariance matrix Ω is presented:

$$\Omega = \begin{bmatrix} \mathbf{1} & \text{PCAISF} & \text{PCASSI} & \text{PCAAF} & \text{PCACD} & \text{PCAILF} & \text{PCAIWI} & \text{PCAPH} \\ \text{PISFCA} & \mathbf{1} & \text{PISFSSI} & \text{PISFAF} & \text{PISFCD} & \text{PISFILF} & \text{PISFIWI} & \text{PISFPH} \\ \text{PSSICA} & \text{PSSIISF} & \mathbf{1} & \text{PSSIAF} & \text{PSSICD} & \text{PSSIILF} & \text{PSSIIWI} & \text{PSSIPH} \\ \text{PAFCA} & \text{PAFISF} & \text{PAFSSI} & \mathbf{1} & \text{PAFCD} & \text{PAFILF} & \text{PAFIWI} & \text{PAFPH} \\ \text{PCDCA} & \text{PCDISF} & \text{PCDSSI} & \text{PCDAF} & \mathbf{1} & \text{PCDILF} & \text{PCDIWI} & \text{PCDPH} \\ \text{PILFCA} & \text{PILFISF} & \text{PILFSSI} & \text{PILFAF} & \text{PILFCD} & \mathbf{1} & \text{PILFIWI} & \text{PILFPH} \\ \text{PIWICA} & \text{PIWIISF} & \text{PIWISSI} & \text{PIWIAF} & \text{PIWICD} & \text{PIWIILF} & \mathbf{1} & \text{PIWIPH} \\ \text{PPHCA} & \text{PPHISF} & \text{PPHSSI} & \text{PPHAF} & \text{PPHCD} & \text{PPHILF} & \text{PPHIWI} & \mathbf{1} \end{bmatrix}$$

The coefficient of pairwise correlation of the error terms of any two of the estimated adoption equation of CSA practices in the model represented by ***p*.**

Explanation of the variables

The study variables were grouped in to independent and dependent variables.

Dependent Variable

Climate change perception: indicates farmers' perception of climate change (rainfall and temperature), emerging effects of climate change on the environment, and agriculture production systems. Farmers' awareness about climate change is crucial for making adaptation-based decisions (Maddison, 2006). Perception is highly influential in raising awareness and influencing implementation decisions to adopt CSA practices. Numerous elements may have an impact on CSA practices adoption, including demographic, socioeconomic, and institutional. According to Saguye (2017), demographic, socioeconomic, and institutional variables were discovered to have a considerable impact on the tendency of farmers perceiving climate change and variability. Based on negative effects of climate change and variability questions, Likert scale with five points, (1 for very low, 2 for Low, 3 for Medium, 4 for High, and 5 for very high) was developed to assess respondents' perceptions of climate change. The values of perception level of an individual farmer was computed by adding the value of each item together and dividing it by the total number of items then marked it out of 5. Categorical ordered variable representing farmer's climate change perception while taking the value of 1 to 5 (from very low perception level to Very high perception level).

Climate smart agriculture practices adoption: One of the response variables is multiple binary outcome (multivariate variate) representing the CSA adoption of the farmers, with a value of 1 for an adopter and 0 for a non-adopter.

Independent Variables

The following explanatory variables are hypothesized to influence farmers' perceptions of climate change and household decisions to implement CSA practices. It include demographic, socioeconomic, and institutional factors.

Sex of Household head: This variable is a dummy one, measured 1 for men and 0 for women. Household head sex is one of the important factor in adoption decisions. Sex may have a positive or negative impact on their decisions and perceptions of climate change and variability. Women farmers, compared to men, are frequently restricted from accessing productive resources in Sub-Saharan Africa (Kangogo et al., 2021). Being male farmer positively influenced the adaptation of agro-ecological practices (Mihiretu et al. 2019).

Age of household head: Household age can represent experience (Tazeze et al., 2012). In the study, it is a continuous variable measured in year. According to Akrofi-Atitianti et al. (2018), as farmers get older, they are more prone to use CSA, but this tendency eventually fades as they get older.

Education level: It is a categorical variable. An individual's educational status will aid in determining available technology and understanding new information. It is a categorical variable. According to a study by Kangogo et al. (2021), education correlates positively with the use of seeds that are approved and soil testing, practices that require financial commitment on the part of the farmer.

Family size: This implies how many individuals reside together in the same home. It is a continuous variable measured in numbers. The number of family member has a contribution for implementation of agricultural technology since labor is an important factor especially for labor-intensive work.

According to studies by Destaw and Fenta (2021); Tazeze et al. (2012), as family size increases, so does adaptation to various options, because farming practices are known labor intensive, and household labor is the primary source of work force in the Ethiopia.

However, there is the possibility for households to share parts of their labor force for daily income to cover the cost of different household consumptions. Hence, family size can affect the CSA adoption decision either negatively or positively.

Farm Land Size: It is cultivable land owned by the farmers. It is a continuous variable assessed and measured in hectares. Studies' output indicates mixed results regarding this variable. While some have found that large farm holders are more inclined to adopt, others have found no such effect or found positive results for certain technologies and negative effects for others (Kangogo et al., 2021). This variable in this study will affect CSA adoption positively or negatively.

Farming Experience: It is expected that the farming experience help the farmers’ access diversified information, probably affecting their adoption decisions for CSA practices. This is a continuous variable with years as the unit of measurement. Study by Mihiretu et al. (2019), indicates, practical farming years rather than living longer are affecting positively the adaptation choices of farmers. This independent variable will affect farmers' perception about climate change and their decisions to use CSA practices.

Livestock holding: Livestock is an important asset for farmers, especially in developing countries including Ethiopia, and it is measured in terms of TLU (Tropical Livestock Unit), thus it is a continuous variable (see annex Table 4). For easing, the work of agriculture as compared with labor, having many livestock, such as oxen, is an important asset as it helps for traction. Owning assets, such animals, is important and positively connected with the choice to implement the following adaption techniques: soil conservation, soil conservation and tree planting, soil conservation and intercropping, and a combination of all three strategies (Beyene et al., 2017). In contrast to Beyene et al. (2017), livestock in TLU had no effect on the household’s adaptation to climate change strategy choices (Mihiretu, et al., 2019). As a result, the impact of livestock up on adoption decisions under CSA practices may differ by livestock species.

Total Livestock holding = $\sum_{i=1}^{n} TLU$

When i=TLU of the farmers' livestock species, n=the total number of each kind of livestock. One TLU is equivalent to 250 kg live weight of livestock (Ayalneh and Abebaw, 2009).

Annual Farm Income: Farm revenue is the annual total of the earnings from both crops and livestock. It is a continuous variable measured Birr in thousand. Households increased their annual income from a variety of farming operations, primarily from the sale of livestock and agricultural products, which expands the window for considering alternate adaptation strategies for climate change (Mihiretu et al., 2019). Therefore, it is anticipated that farm income will boost the likelihood of CSA practices adoption.

Farming system: It is the means of life for farmers and is divided into three categories: 1 = for farmers who rely solely on crop production; 2 = for those who rely solely on livestock rearing; and 3 = if farmers are working on both crop production and livestock rearing. This variable is likely to affect the uptake of CSA practices positively.

Access to Services for Credit: The financial resource of credit is what enables farmers to bridge their current financial gap. This variable is a dummy one that takes the value of 1 for farmers have access to credit and 0 otherwise. Among the explanatory factors that influenced farmers' adaptation choices favorably and significantly, one was access to credit services (Mihiretu et al. 2019). Ojoko et al. (2017) revealed that access to services for credit was one key factors influencing CSA implementation in Sokoto State, Nigeria. The study result by Kangogo et al. (2021) reveals that access to credit was favorable correlation with the implementation of costly practices such as approved seed and soil testing practices. Hence, access to credit has a positive impact on CSA adoption decisions, as hypothesized.

Access to Agricultural Extension services and agricultural training: An agricultural extension system serves as the conduit for the exchange of agricultural knowledge between the agriculture office and the farmers. Extension services like advisory services from the DA and home-to-home visits help farmer's access agricultural information. This variable is a dummy one, with 1 representing individuals who have access to extension services & training and 0 representing those who do not. The frequency of extension contact influenced farmers' adaptation choices positively and significantly (Mihiretu et al., 2019).

Access to training will assist farmers in gaining access to information. Farmers' adoption behavior was assumed influenced positively by access to agricultural training (Belay, 2003).

Field day participation: Participating in field days gives farmers a valuable opportunity to see how various agricultural technology are used. The great significance and purpose of field days and trips has been to the farming community and agricultural experts to new techniques of agriculture so that participants might observe how technology and approaches are actually applied (Heiniger et al., 2002). This independent variable, treated as a dummy, is set to 1 for field day participation and 0 otherwise and is expected to positively affect perceptions of climate change, variability, and CSA adoption.

Table 3 Types and description of the study Variables

Variables	**Types of variables**	**Description of the variables**	**Expected Sign**
		Dependent variables	
Climate change perception	Categorical ordered variable	1 for very low,2 for low,3 for medium,4 for High and 5 for very high	
CSA practices adoption	Dummy variable	1 if CSA adoption 0, other wise	
		Independent variables	
Household Sex	Dummy	1 if House hold head is male 0, otherwise	+ / –
House hold age	continuous	Household head age measured in years	+
Education level	Categorical	**i**=unable read and write, **ii**= grade1-4, **iii** =grade 4-8, **iv**= grade 9-12,**v**=above grade12	+
Family size	Continuous	Household members living together	+/-
Farm land size	Continuous	Farm land size of the household	+ / –
Experience in agriculture	Continuous	Households farm experience in year	+
Livestock holding	Continuous	Livestock owned by house hold in TLU	+
Income from farm	Continuous	Household annual farm income in Birr in thousand	+
Household farming system	Categorical	**i**=crop production, **ii**= livestock production, **iii**=both crop production and livestock rearing	+

Access to credit services	Dummy	1 if access to credit 0, otherwise	+
Agri. extension services access and agricultural training	Dummy	1 if accesses to agricultural extension services & training 0, otherwise	+
Field day participation	Dummy	1 if access to field day participation 0, otherwise	+

Temperature and rainfall data analysis

The meteorological data including temperature and precipitation information for the research area were received from Ethiopian Meteorology Institute. Both rainfall and temperature data were used to see the climate variability trend of the study area.

The analysis of these data employed; different methods. The precipitation concentration index (PCI) was used to determine uniformity of rainfall distribution. It is useful for measuring and calculating the proportional distribution of precipitation patterns and presenting the spatial variability of monthly precipitation. (Gocic et al., 2016).

$$PCI_{annual} = \frac{(\sum Pi^2)}{(\sum Pi)^2} * 100 \text{...} 3.5.12$$

Where PCI is the precipitation concentration index, Pi is the rainfall record for i^{th} months of the year, and = the sum of the rainfall value of months of a year.

PCI value **< 10** indicates uniformly distributed rainfall, **11 ≤ PCI ≤ 15** moderate precipitation distributions, **16 < PCI < 20** irregular precipitation distribution and **PCI > 20** Strong irregular distribution (Gocic et al., 2016).

Temperature and rainfall variability analysis is determined mathematically by the coefficient of variation (CV). The following formula was used to calculate the annual and monthly CV of rainfall and temperature (Agrawal, 2010).

$$CV = \frac{\frac{\sqrt{\sum f(xi-\bar{x})^2}}{n}}{\bar{x}} = \frac{\sigma}{\bar{x}} \text{ ....3.5.13}$$

Where $\boldsymbol{xi}$ = the annual rainfall in millimeters of the ith year of a given station, $\bar{x}$ = the mean of yearly rainfall in mm, $\boldsymbol{n}$ = the total years number the data were obtained, $\boldsymbol{\sigma}$ = standard deviation.

Rainfall with a CV value of < 20% is less variable, rainfall with a CV value of between 20% and 30% is a bit irregular, and rainfall with a CV value of > 30% or greater is highly variable (NMSA. 1996).

Standardized or unified anomaly index (*SAI*) to find out changes in average temperature over time or across the years calculated using the following formula: -

$$\boldsymbol{SAI = \frac{Tav-Tm}{\sigma}} \text{ ....3.5.14}$$

Where $\boldsymbol{T_{av}}$ is the average annual or a year temperature, $\boldsymbol{Tm}$ is average temperature over the time of 1991 to 2021 and σ is standard deviation of over the time average temperature.

The rainfall anomaly index is calculated as follows to assess the frequency of occurance and intensity of dry and rainy years:

$$\boldsymbol{Z = \frac{Xi-Yi}{std}} \text{ ....3.5.15}$$

Where; ***Z, Xi, Yi*** and ***std.*** are the standard rainfall anomaly, the rainfall of a specific year, the long-term mean annual or seasonal precipitation, and the standard deviation of the annual or seasonal rainfall of the observed period. (1991 to 2021).

The rainfall anomaly index intensity result was classified as follows: RAI > 4(extremely or highly humid), 2 ≤ RAI ≤ 4 (very humid), 0 ≤ RAI ≤ 2 (humid), -2 ≤ RAI ≤ 0 (dry), -4 ≤ RAI ≤ -2 (very dry) and RAI<-4 (extremely or highly dry) (Hare, 2003).

Mann-kendall (MK): Mann-kendall statistics has been applied by different scholars for trend analysis of hydro-meteorological data Gocic, and Trajkovic, (2013); Salmi et al., (2002).

It is a non-parametric test to see increasing or decreasing trends of seasonal and annual temperature and rainfall (Kendal, 1975). The magnitude of change was determined using Theil-Sen's slope estimator. The Mann-Kendall as well as Sen's slope estimator are less susceptible to outliers (Salmi et al., 2002). The test statistics for Mann-Kendall (MK) test ***S*** are given as follows:

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sng(x_j - x_i) \quad \text{3.5.16}$$

Where x_i and x_j are the annual sequential uneven climate values in years i and j in the order already mentioned.

$$sng(x_j - x_i) = \begin{cases} 1 \; if x_j - x_i > 0 \\ 0 \; if x_j - x_i = 0 \\ -1 \; if x_j - x_i < 0 \end{cases} \quad \text{3.5.17}$$

Mann-Kendall's test essential principles comprehend the assessment of the sign of all pairwise variation or differences of the values of observation (Mann, 1945; Kendall, 1975). A positive ***S*** value to show increasing trends, while a negative S value implies decreasing trends in the data series.

In the condition where there is data with equal values (ties) in the *x* values; the variance of *S* is solved as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} ti(ti-1)(2ti+5)}{18} \quad \text{3.5.18}$$

Where m= the number of data with equal values (tied) group in the data set and ti=the number of data point in the i^{th} tied group. If n > 10, Z_S (the standard normal distribution) solved using the following equation:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & if \; S > 0 \\ 0, & if \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & if \; S < 0 \end{cases} \quad \text{3.5.19}$$

The positive ***S*** values shows rising tendencies, and the negative ***S*** values (see equation 3.5.22) indicate decreasing trends. However, statistically significant trend will be tested using the $\mathbf{Z_{MK}}$ value. The null hypothesis (H_O) rejected if the value of **$|Z_{MK}|$ is greater than $\boldsymbol{Z_{1-\frac{\alpha}{2}}}$** at a given level of significant. $\boldsymbol{Z_{1-\frac{\alpha}{2}}}$ critical value of Z_S is obtained from normal probability table (for 5% significance level, the value of $Z_{1-\frac{\alpha}{2}}$ is 1.96, and for a 1% significance level, the value of $Z_{1-\frac{\alpha}{2}}$ is 2.576). In this analysis, the null hypothesis was tested at a 95% confidence level (α=5%).

Sen's slope estimator is a non-parametric technique devised by Sen (1968) Salmi et al., (2002), for estimating the slope of N pairs of data:

$$\mathbf{Qi} = \frac{xj - xk}{j - k} \text{ for i= 1,........,N} \quad \textbf{..3.5.20}$$

Where ***xj*** and ***xk*** are values of data at time ***j*** and ***k*** respectively and ***j>k.***

If there are only one datum in each time period and n is the number of time period We obtain as many as, **N=** $\boldsymbol{\frac{n(n-1)}{2}}$ estimated slopes ***Qi***. If there are multiple data in one or more-time periods, < $\boldsymbol{\frac{n(n-1)}{2}}$ **,** where **n** is the total number of observation. The Sen's estimator of slope is the central or median of these **N** values of ***Qi***. The ***N*** values of ***Qi*** are sequenced or ranked from the smallest or the lowest value to the largest and the Sen's slope estimator according to Gocic, and Trajkovic, (2013); and Salmi et al., (2002) is:

$$\boldsymbol{Q_{med}} = \begin{cases} Q_{[(N+1)/2]}, & if\ N\ is\ Odd \\ \frac{Q_{[N/2]} + Q_{[(N+2)/2]}}{2}, & \text{if N is even} \end{cases} \quad \textbf{..3.5.21}$$

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

This section contains results and discussions of the study. The result is the answers for the study questions, which includes what factors affects climate change perception, CSA practices implementing in the study area, rate of adoption of CSA practices and determinant factors for adoption of CSA practices.

4.1.Descriptive analysis

The analysis of the data employed descriptive statistic for analysis of mean deference of explanatory variables between climate change perception level of respondents and adopters & non-adopters for identified CSA practices in the area. The chi2-test as well as the t-test were used to see the variations between users and non-users of CSA practices. Ordered logit and Multivariate probit models were used to determine what variables influences farmers' climate change perception and adopters' determinants of CSA practices respectively.

CSA is an approach that demands location-specific assessments to identify suitable agricultural production technologies and practices to address the complex issues of climate change (FAO, 2013). Agricultural conservation practices, Management of integrated soil fertility, Small-scale irrigation, Agroforestry practices, Crop diversification, Improved practices of livestock feed and feeding, Conservation of water for agriculture, Early-warning and information system for improved weather, Optional energy, Insurance for crop and livestock, Diversified Livelihoods and Post-harvest technologies (agro-processing, storage) are some of CSA practices implementing in Ethiopia (Jirata et al., 2016).

CSA practices implementing in the research area identified. It includes conservation agriculture which includes soil or stone bund, limited tillage, management of crop residue and mulching, and crop sequencing; Management of integrated soil fertility includes compost, management of manure and efficient fertilizer; Small-size irrigation includes year round cropping and efficient water use; Agroforestry practice includes tree based conservation and natural regeneration managed by farmers; diversification of crop including pest and disease tolerant, high yielding and short season crops; Improved livestock feed and feeding incudes reduced or minimum grazing, development of a variety of forage, improvement of livestock feed and breed; Improved weather information, and Post-harvest technologies with at least 5 years (mulching) since the start of the implementation of the practices.

Table 4 Description of Study Factors

Dependent Variables(CSA practices)	Description	Mean	Std. Dev.
Conservation practices of Agriculture	Dummy=1 if farmers adopt the practice, 0 otherwise	0.418	0.494
Improved soil fertility	Dummy=1 if farmers adopt the practice, 0 otherwise	0.611	0.488
Small size irrigation	Dummy=1 if farmers adopt the practice, 0 otherwise	0.382	0.487
Agroforestry	Dummy=1 if farmers adopt the practice, 0 otherwise	0.333	0.472
Crop diversification	Dummy=1 if farmers adopt the practice, 0 otherwise	0.484	0.501
Improved Livestock feed and feeding	Dummy=1 if farmers adopt the practice, 0 otherwise	0.363	0.482
Improved weather information	Dummy=1 if farmers adopt the practice, 0 otherwise	0.353	0.479
Postharvest technology	Dummy=1 if farmers adopt the practice, 0 otherwise	0.386	0.488
Independent Variables			
Sex	Dummy=1 if farmers sex is male, 0 otherwise	0.846	0.361
Age	A continuous variable measured in year	47.5	11.59
Education	unable to read& write=1, grade1-4=2, grade5-8=3, grade9-12=4, >grade12=5	2.297	0.941
Perception level	Categorized as 1 for very low, 2 for low ,3 for medium, 4 for High and 5 for very high	3.892	0.912
Family size	A continuous variable measured in number	5.9	1.96
Farm land size	A continuous variable measured in ha	1.8	0.90
Farming system	only crop=1, only livestock=2, Both=3	2.961	0.278
Income from farm	Households Farm income Birr in thousand	23.830	19.530
Credit service access	Dummy=1 if farmers access to credit, 0 otherwise	0.343	0.476

Livestock holding	Livestock holding in TLU	5.542	2.492
Access to Agri. Ext. services & agri. Training	Dummy=1 if farmers access to agri.ext. and training, 0 otherwise	0.461	0.499
Farmers field day participation	Dummy=1 if farmers access to field day participation, 0 otherwise	0.356	0.480

4.1.1. Respondents socio-economic and institutional characteristics

The study takes into account explanatory variables that can impact the implementation of CSA practices and degrees of perception of climate change, which include gender, age, educational attainment, family size, farming system, farmland size, livestock holding (TLU), farm income, credit service access, access to agricultural extension & training, access to field day participation, and climate change perception. These variables are displayed in tables 6, 7, 8, 9, 10, 11, 12, and 13. From the total randomly selected sample HHs, 47 (15.4%) were HHs headed by women and 259 (84.6%) were male-headed HHs, and this outcome is almost comparable to national data by the CSA (2012), which shows that about 16% of households were women-headed.

One's perspective of a particular notion affects how they decide or perceived. In this study, it was perceived that, a farm household's understanding of climate change enables them to do something in reaction to the catastrophic impacts associated with climate change on agricultural production. In this instance, a Likert scale was used to assess farmers perception about climate change. The development of the items for the Likert scale is on different climate change aftermaths. The climate change aftermaths are basically depend on literature and meteorological data result of rainfall and temperature. The scale was measured from 1 to 5 points (1 for strongly disagree, 2 for disagree, 3 for neither agree nor disagree, 4 for agree, and 5 for strongly agree), thus the value of the farmers perception level has ordered value.

Perception levels in terms of educational level vary and significant at 1% level.

Table 5 Households characteristics of Climate change perception / dummy and categorical variables

Variables		1 n=12	2 n=62	3 n=80	4 N=107	5 n=45	Chi2
Household sex	Male	66.7	82.3	83.8	84.1	95.6	7.4484
	Female	33.3	17.7	16.3	15.9	4.4	
Educational status	No read and write	16.7	12.9	17.5	31.8	53.3	55.4765***
	Grade 1-4	25	17.7	23.8	31.8	11.1	
	Grade 5-8	33.3	21	37.5	20.6	24.4	
	Grade 9-12	25	48.4	21.3	15.9	11.1	
	> Grade 12	0	0	0	0	0	
Access to Agriculture Ext. & agricultural training	YES	8	32	42.5	51	69	12.7
	NO	92	68	57.5	49	31	
Access to credit services	YES	25	34	35	31	44	3.105
	NO	75	66	65	69	56	

Source: Survey data (May 2022), Note: ***, **,*= significant at 1%, 5% and 10% respectively

The result babbles out that among adopters of conservation agriculture, 89.1% of homes had men as the head, compared to10.9% of families led by women. The descriptive result in Table 6 confirmed that there was significant variation between those who adopt and those who do not of agricultural conservation practices in terms of head of household sex at 10% significant level.

Adopters and non-adopters categories of agricultural conservation practices have significant differences in terms field day participation (chi2=5.18; $p<0.05$).Variability in field day participation between adopters and non-adopters of conservation agriculture practices was significant at the 5% level.

Table 6 Households characteristics of adopters and non-adopters of Conservation agriculture (dummy and categorical variables)

variables		Adopters n=128	Non-adopters n=178	Total n=306	chi2
Sex	Male	89.1	81.5	84.6	3.31*
	Female	10.9	18.5	15.4	

Educational level	Unable to read and write	37.5	19.1	26.8	6.04
	Grade 1-4	24.2	23.0	23.5	
	Grade 5-8	18.0	32.0	26.1	
	Grade 9-12	20.3	25.8	23.5	
Access to Agriculture Ext. and agricultural training	YES	47.7	44.9	46.1	
	NO	52.3	55.1	53.9	0.2205
Field day participation	YES	43	30.3	35.6	5.18**
	NO	57	69.7	64.4	
Access to credit services	YES	29.7	37.6	59	2.089
	NO	70.3	62.4	41	

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 respectively

Management of integrated soil fertility is one of the CSA practices Ethiopian farmers are implementing. Table 7 below shows that among 84.6% of the total households led by men, 158 were adopters and 101 were non-adopters of integrated soil fertility management. The Chi^2 test confirmed that differences between adopters and those who do not in terms of household sex, which was significant at 10%.

Field days are impactful in convincing farmers about the benefit and essentialness of the demonstrated technology. From the total number of adopters of integrated soil fertility management, 47.22% of them had access to field day participation, while only 19% of non-adopters had field day participation access. Chi^2 test result confirmed that there was a statistically significantly difference between adopters and those who do not at 1% level.

Credit services help farmers get relief from their financial deficits by providing them with money in the form of credit. From 180 respondents who adopted integrated soil fertility management, 30.6% and from 126 non-adopters respondents, 39.7% of them had credit service access. The Chi^2 - test result reveals significant variation at 10% level between those who implement management of integrated soil fertility and those who do not in terms of credit service access.

Table 7 Households traits of adopters and non-adopters of integrated soil fertility management (dummy and categorical variables)

Variables		Adopters n=180	Non-Adopters n=126	Total n=306	chi2
Sex	Male	87.8	80.2	84.6	3.309*
	Female	12.2	19.8	15.4	
Educational level	Unable to read and write	31.1	20.6	26.8	4.612
	Grade 1-4	21.1	27.0	23.5	
	Grade 5-8	24.4	28.6	26.14	
	Grade 9-12	23.3	23.8	23.5	
Access to Agriculture Ext. and agri training	YES	56.1	31.7	46.1	6.67
	NO	43.9	68.3	53.9	
Field day participation	YES	47.2	19	35.6	22.54***
	NO	52.8	81	64.4	
Access to credit services	YES	30.6	39.7	34.3	2.74*
	NO	69.4	60.3	65.7	

Source: Survey data (May 2022), Note: ***, **,*=significant at 0.01, 0.05 and 0.1 as orderly mentioned.

Small-scale irrigation is one of the CSA practices used by Ethiopian farmers. According to the result in Table 8 below, there was no variability between those who implement and non-adopter respondents in terms of household head sex. The variability between those who adopt and non-adopters of small-scale irrigation in terms of education was significant at 10% level (Chi ^{2} = 6.6146 and p value = 0.085).

Out of all adopters of small-scale irrigation practices (117 respondent), 41.88% of them and from the total non-adopters (189 respondent), 31.7% of them have access to field day participation. The Chi2-test result confirmed that there is significant variation between those who adopt and those who do not in terms of access to field day participation at 10% level. Likewise, of the total adopters, 44.4%, and of the total non-adopters, 28%, of the respondent farmers have access to credit services. The Chi2-test result confirmed that there is substantial variation between those who adopt and those who do not in terms of credit services access at 1% level.

Table 8 Households traits of adopters and non-adopters of Small-scale irrigation (dummy and categorical variables

Variables		Adopters n=117	Non-Adopters n=189	Total n=306	chi2
Sex	Male	82.9	85.7	84.6	0.4384
	Female	17.1	14.3	15.4	
Educational level	No read and write	33.3	22.8	26.8	6.6146*
	Grade 1-4	17.1	27.5	23.5	
	Grade 5-8	24.8	27.0	26.1	
	Grade 9-12	24.8	22.8	23.5	
Access to Agriculture Ext. services & agri. training	YES	47.9	45	46.1	0.242
	NO	52.1	55	53.9	
Field day participation	YES	41.9	31.7	35.6	3.236*
	NO	58.1	62.3	64.4	
Access to credit services	YES	44.4	28	34.3	8.625*
	NO	55.6	72	65.7	

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Agroforestry practices are CSA practices that are expected to significantly contribute to reducing the effects of climate change on agriculture. The focus group discussion results confirmed that farmers are planting various types of trees to conserve farm and degraded lands. However, the extensive animal production system, which is characterized by open grazing systems in rural areas, was the main challenge for planted trees to grow, and the FGD response was in agreement with the study by (Jirata et al., 2016).

The chi^2-test result implied that there was no variability in terms of respondents' sex between adopters and non-adopters of agroforestry practices. Respondents differ in their decision to adopt agroforestry practices based on their educational level, which is significant at 5%.

From the total number of adopters of agroforestry practices, 39.22% of them and 49.5% of the total of non-adopters have agricultural extension and agricultural training service access. The descriptive statistic result on Table 9 confirmed that the variability between adopters and non-adopters of the practices in terms of access to **a**griculture Extension services and agricultural training was significant at 10% level. Likewise, the chi^2-test result confirmed that the variation in access to credit services between those who adopt and non-adopters was significant at 5% level.

Table 9 Households traits of adopters and non-adopters of agroforestry (dummy and categorical variables)

Variables		Adopters n=102	Non-Adopters n=204	Total n=306	chi2
Sex	Male	81.4	86.3	84.6	1.2569
	Female	18.6	13.7	15.4	
Educational level	Unable to read and write	29.4	25.5	26.8	8.259**
	Grade 1-4	20.6	25.0	23.5	
	Grade 5-8	18.6	29.9	26.1	
	Grade 9-12	31.4	19.6	23.5	
Access to Agriculture Ext. and agricultural training	YES	39.2	49.5	46.1	2.9*
	NO	60.8	50.5	53.9	
Field day participation	YES	34.3	36.3	35.6	0.114
	NO	65.7	63.7	64.4	
Access to credit services	YES	44.1	29.4	34.3	6.524**
	NO	55.9	70.6	65.7	

Source: Survey data (May 2022), Note: ***, **,*=significant at 1%, 5%and10% respectively

Improved crop varieties include high yielding varieties, resistance varieties (resistance to biotic factors like insects and parasites that could be sources for different crop diseases, while resistance to abiotic factors includes extreme weather conditions like heat, drought, cold, etc.), and varieties with a short maturity period.

Male-headed households account for 137 (92.6%) of the total adopters and 122 (77.2%) of the total non-adopters of improved crop varieties. The chi2-test result indicated in Table 10 implies that variability between those who adopt and those who do not adopt crop diversification in terms of sex was significant at 1% level. The chi^2 result indicated that there was significant variability between those who adopt and those who do not adopt crop diversification in terms of level of education at 10% level.

Farmers' access to agriculture extension services and agricultural training indicated that 71.6% of improved crop variety adopters and 22.2% of non-adopter respondents have accessed agricultural extension services. The Chi^2-test result reveals that there is significant variation at 1% level among respondents in terms of extension service access. It implied that the importance of agricultural extension delivery is inevitable for disseminating improved crop variety technology. Agricultural training is a means of acquiring different skill of farming. There is statistically significant variation between who adopt and those who do not adopt of crop diversification in terms of agricultural extension and agricultural training service access. People Category of the People who use and who do not of crop diversification significantly different in terms of access to field day participation at 1% level. Similarly, the variability between those who adopt and those who do not adopt in terms of credit service access was significant at 10%.

Table 10 Households traits of adopters and non-adopters of crop diversification (dummy and categorical variables)

Variables		**Adopters n=148**	**Non –Adopters n=158**	**Total n=306**	**chi2**
Sex	Male	92.6	77.2	84.6	13.855***
	Female	7.4	22.8	15.4	
Educational level	Unable to read and write	31.8	22.2	26.8	6.3583*
	Grade 1-4	20.3	26.6	23.5	
	Grade 5-8	28.4	24.1	26.1	
	Grade 9-12	19.6	27.2	23.5	
Access to Agriculture Ext. and agricultural training	YES	71.6	22.2	46.1	75.27***
	NO	28.4	77.8	53.9	
	YES	55.4	17.1	35.6	48.92***

Field day participation	NO	44.6	82.9	64.4	
Access to credit services	YES	39.2	29.7	34.3	3.02*
	NO	60.8	70.2	65.7	

Source: Survey data (May 2022) Note: ***, **,*= significant at 0.01, 0.05 and 0.1 as orderly mentioned.

Climate change has an effect on animal production in a variety of ways. It may increase the coverage of shrubs in some grassland areas, causing the quality and amount of fodder available to livestock to decline (Hidosa and Guyo 2017).

Hence, adoption of practices of improved livestock feed and feeding, besides breed improvement, is of great significance for the farming community. Male-respondent farm households accounted for 92.8% of total adopters, while female-respondent farm households accounted for 7.2%.The chi2-test result confirms significant variability between those who adopt and those who do not in terms of household sex at 1% level.

Table 11 Households characteristics of adopters and non-adopters of improved livestock feed & feeding practices (dummy and categorical variables)

Variables		Adopters n=111	Non-Adopters n=195	Total n=306	chi2
Sex	Male	92.8	80	84.6	8.9046***
	Female	7.2	20	15.4	
Educational level	Unable to read and write	27.0	26.7	26.8	1.0866
	Grade 1-4	20.7	25.1	23.5	
	Grade 5-8	26.1	26.2	26.1	
	Grade 9-12	26.1	22.1	23.5	
Access to Agriculture Extension services and agricultural training	YES	50.5	43.6	46.1	1.34
	NO	49.5	56.4	53.9	
Field day participation	YES	39.6	33.3	35.6	1.23
	NO	60.4	66.4	64.4	
Access to credit services	YES	31.5	35.9	34.3	0.59
	NO	68.5	64.1	65.7	

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.10 in the order already mentioned.

In the agricultural production systems, weather information plays a significant role for adjusting to the changing climate. The FGD discussion results confirmed crop production the primary farming activity for farmers in the study areas; thus, weather information is an important factor in determining whether to plant early or late based on the start of the rainy season and the adoption of various CSA practices. Thus, the chi2-test result shows that significant difference between those who adopt and non-adopt improved weather information in terms of education level at 10% level.

Table 12 Households characteristics of adopters and non-adopters of improved weather information (dummy and categorical factors)

Variables		Adopters n=119	Non-Adopters n=187	Total n=306	chi2
Sex	Male	88.2	82.4	84.6	1.9356
	Female	11.8	17.6	15.4	
Educational level	Unable to read and write	18.5	32.1	26.8	7.1927*
	Grade 1-4	26.1	21.9	23.5	
	Grade 5-8	27.7	25.1	26.1	
	Grade 9-12	27.7	20.9	23.5	
Access to Agriculture Ext. services& agri. training	YES	59.7	37.4	46.1	1.307
	NO	40.3	62.6	53.9	
Field day participation	YES	43.7	35.8	38.9	5.54**
	NO	56.3	64.2	61.1	
Access to credit services	YES	29.4	37.4	34.3	2.08
	NO	70.6	62.6	65.7	

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Most likely, pests are reproducing more easily because of climate change. It will cause harm to the crop, as a result, agricultural products are prone to pests like weevils, which can harm the harvested crop, if they are not properly managed after harvest. The Chi2-test result in Table 13 reveals that there is variability between adopters and non-adopters of post-harvest technology in terms of household sex and education level at 10% significant level; however, the variability among respondents in terms of field day participation is significant at 5% for field day participation.

Table 13 Households characteristics of adopters and non-adopters of Post-harvest technology (dummy and categorical variables)

Variables		Adopters n=118	Non-adopters n=188	Total n=306	chi2
sex	Male	88.9	81.7	84.6	2.9738*
	Female	11.1	18.3	15.4	
Educational level	Unable to read and write	37.3	18.7	26.8	14.689*
	Grade 1-4	23.8	22.5	23.5	
	Grade 5-8	18.3	30.5	26.1	
	Grade 9-12	20.6	24.6	23.5	
Access to Agri. Ext. services and agricultural training	YES	50.8	43.1	46.1	0.20
	NO	49.2	56.1	53.9	
Field day participation	YES	46.6	28.7	35.6	4.836**
	NO	53.4	71.3	64.4	
Access to credit services	YES	32.2	35.6	34.3	1.64
	NO	67.8	64.4	65.7	

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Families who farm both crops and animals diversify their sources of income and are likely to make more money than those who exclusively grow crops. In addition to the previously mentioned reason, livestock provides traction power for farmers in many rural areas of Ethiopia and simplifying farming tasks. In this regard, having many livestock, especially large ruminants, is advantageous. The difference between adopters of conservation agriculture in terms of age, family size and land size is significant at 1% (P<0.000). Similarly, the mean livestock holding in terms of TLU for those who adopt and not adopt of practices of conservation agriculture were 6.37 and 4.95, respectively, and confirms that there is a significant difference at 1% level between the two categories.

Table 14 Households Characteristics of adopters and non-adopters of conservation agriculture

	Non-adopters		**Adopters**			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value

Age	45.52	11.49	50.32	11.19	-3.64***	0.000
Family Size	5.6	1.95	6.4	1.9	-3.10***	0.000
Land Size	1.33	0.7	2.38	0.8	-12.1***	0.000
Livestock Holding (TLU)	4.95	2.321	6.37	2.492	-5.132***	0.000
Farm income	22.24994	20.90065	26.0332	17.29794	-1.676	0.100

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

The variability between adopters and non-adopters of integrated soil fertility management in terms of family size and land size is significant at 5% and 1% respectively. The mean livestock holding in terms of TLU for adopter and non-adopter was 5.8 and 5.2 respectively and the variability among adopters and non-adopters of integrated soil fertility management was significant at 5%.

Table 15 Households characteristics of adopters and non-adopters of integrated soil fertility management

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	46.81	11.25	47.98	11.82	-0.8629	0.389
Family Size	5.6	1.8	6.1	2.0	-2.280**	0.0233
Land Size	1.4	0.71	2.0	0.94	-5.94***	0.000
Livestock Holding (TLU)	5.167	2.619	5.803	2.371	-2.215**	0.027
Farm income	22.50794	19.01428	24.75967	19.89048	-0.992	0.321

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Adopters and non-adopters categories of small scale irrigation are significantly vary in terms of age.TLU for adopter and non-adopter of small size irrigation were 4.76 and 6.03, in the order already mentioned, and the difference was significant at 1% level (t-test = 4.47 and

P-value = 000), indicating that there was a positive correlation between size of livestock holding and adoption of small-scale irrigation.

Table 16 Households characteristics of adopters and non-adopters of Small-scale irrigation

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	46.3	9.3	49.5	14.43	-2.315**	0.0213
Family Size	6.1	5.73	1.88	2.08	1.444	0.149
Land Size	1.78	0.80	1.75	1.05	0.228	0.819
Livestock Holding (TLU)	6.03	2.567	4.76	2.154	4.47***	0.000
Farm income	24.95508	20.79629	22.01906	17.23479	1.279	0.201

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Respondents age and farmland size significantly vary for adopters and non-adopters of agroforestry practices at 5% and 10% level. Livestock holdings in terms of TLU for those who adopt and those who do not of agroforestry practices were 5 and 5.8, respectively, and the t-test result was found significant at the 5% level (t-test = 2.929 and P-value = 0.003), indicating that there was a correlation between having a large livestock number and implementing agroforestry practices.

Table 17 Households characteristics of adopters and non-adopters of Agroforestry

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	46.34	10.49	49.90	13.29	-2.549**	0.0113
Family size	5.97	1.87	5.87	2.15	0.431	0.667
Land size	1.83	0.91	1.64	0.88	1.78*	0.076
Livestock Holding (TLU)	5.833	2.398	4.958	2.584	2.929**	0.003

Farm income	24.62235	20.16625	22.25275	18.19839	1.000	0.318

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Adopters and non-adopters of crop diversification significantly vary in terms of size of land holding at 1% level. The average annual farm income for adopters of improved crop varieties was 26.09419 Birr in thousand, and for non-adopters, it was 21.714 Birr in thousand. The t-test result from Table 18 reveals that the mean farm income of those who adopt and who do not adopt practices of crop diversification has a statistically significant difference at 10%.

Table 18 Households characteristics of adopters and non-adopters of Crop diversification

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	46.48	10.41	48.65	12.65	-1.643	0.101
Family Size	5.77	1.92	6.12	2.00	-1.556	0.121
Land Size	1.42	0.72	2.15	0.94	-7.68***	0.000
Livestock Holding (TLU)	5.4	2.619	5.7	2.352	-0.715	0.474
Farm income	21.71392	15.42082	26.09419	22.97375	-1.969*	0.049

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Improved livestock feed and feeding practices adopters and non-adopters variability in terms of respondent's age, family size and land size is significant at 10%, 5% and 1% level. Livestock holding in terms of TLU for adopter and non-adopter of improved livestock feed and feeding practice were 6.2 and 5.2 respectively. The t-test result shows statistically significant variation at 1% level.

Average annual farm income for adopters of practices of improved livestock feed and feeding was 35.56802 Birr in thousand, and non-adopters' average annual farm income was 17.15226 Birr in thousand. The t-test result from Table 19 reveals that statistically significant difference at 1% level.

Table 19 Households characteristics of adopters and non-adopters of improved livestock feed & feeding practices

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	46.70	12.15	48.99	10.45	-1.664*	0.097
Family Size	5.77	2.07	6.24	1.74	-2.036**	0.043
Land Size	1.47	0.77	2.30	0.88	-8.65***	0.000
Livestock Holding (TLU)	5.2	2.487	6.2	2.375	-3.505***	0.000
Farm income	17.15226	12.61123	35.56802	23.65339	-8.884***	0.000

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Adopters and non-adopters of improved weather information are significantly vary at 10% in terms of land size. The t-test result from Table 20 confirms that no statistically significant difference between those who adopt and those who do not adopt weather information.

Table 20 Households characteristics of adopters and non-adopters of improved weather information

	Non-adopters		Adopters			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	48.07	11.51	46.55	11.73	1.099	0.272
Family Size	6.00	1.97	5.82	1.97	0.768	0.442
Land Size	1.84	0.96	1.65	0.80	1.653*	0.099
Livestock Holding (TLU)	5.2	2.312	6	2.693	0.8536	0.007
Farm income	21.59139	16.94029	27.3542	22.66082	-0.4568	0.011

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

Post-harvest technology adopters respondents has difference in term of age, family size and land size significantly at 5%, 5% and 1% level respectively. Average annual farm income for adopter of post-harvest technology was 26.125 Birr in thousand and non-adopters average annual farm income was 22.22772 Birr in thousand. The t-test result from Table 21 confirmed that the annual farm income between those who adopt and those who do not adopt was significantly different at 1%.

Table 21 Households characteristics of adopters and non-adopters of Post-harvest technology

	Non-adopters		**Adopters**			
Variables	Average	Standard Deviation	Average	Standard Deviation	t-test	P-value
Age	45.87	11.48	50.19	11.33	-3.219**	0.0014
Family Size	5.69	1.94	6.35	1.95	-2.895**	0.0041
Land Size	1.41	0.80	2.35	0.77	-10.07***	0.0000
Livestock Holding (TLU)	4.99	2.338	6.34	2.497	-1.835	0.000
Farm income	22.22772	20.78545	26.125	17.41877	-1.723*	0.085

Source: Survey data (May 2022), Note: ***, **,*= significant at 0.01, 0.05 and 0.1 in the order already mentioned.

4.2. Analysis of Variability of Climate

Ethiopia's agricultural sector is highly climate-sensitive, extremely susceptible to climate-related shocks, and greatly vulnerable to climate change. Climate change has a significant impact on Ethiopia's farming system (FAO, 2016). Particularly when combined with the nation's capacity for adaptation, it is disastrous.

4.2.1. Trends of temperature

Temperature is an essential element of climate, and it can affect other components of the weather and climate, such as wind, precipitation, and humidity. The temperature across different parts of Ethiopia has dissimilarities, and its extreme events are becoming more common (Dula et al., 2020). The yearly mean temperature in Ethiopia varies by roughly 10 °C, over the highland parts of the Southeast, Central, and Northwest to 35 °C, over the northeastern parts (NMSA, 2001). In the country, it was reported that from 1960 to 2006 alone, the mean temperature rose by 1.3 °C (Jirata et al., 2016). Climate change and variability have had an impact Ethiopia in many directions. Climate variability, including drought, has a significant negative impact on Ethiopia's socioeconomic development (NMSA, 2001).

Meteorological data result indicated that the yearly average maximum temperature over the area varies from 20.2 °C to 26.1 °C and the yearly average minimum temperature over this area varies from 6.4 °C to 10.9 °C. The difference between the annual average temperature over this area for the last three decades (1988–2020) ranges between 14.1 °C and 17.6 °C, indicating that there was temperature variability over the areas recorded during the last three decades.

The area's maximum and minimum temperatures over the previous three decades increased annually by 0.091 °C and 0.040 °C, respectively. The increase in temperature could affect agriculture production and productivity. If the temperature rises above the optimum temperature for crops, it has a negative impact on crop yield.

Even though effects of climate change vary by place, however, according to some research a 1 °C increase in temperature above the mean temperature of 23 °C reduces wheat yield by approximately 10% (Narayanan 2018). The ideal temperature for producing wheat is 15˚C – 20 °C (Liu et al., 2008). It implies that temperatures above the optimum level for crop requirements, as well as temperature variability, can have an impact on food security. This can be a series problem for countries like Ethiopia, due to the case that, together with four other cereal crops (barley, maize, sorghum, and teff); wheat accounts for 75% of the overall area cultivated in the country (Taffesse et al., 2012).

The three decades' anomalies of annual highest, lowest, and mean temperature shows variability between years. The anomaly index result indicate that the trend after 2007 for annual maximum temperature is increasing, unlike that of before 2002 (Figure 4). Average annual minimum temperature SAI (Figure 4), reveals that the mean of minimum temperature in the study area varies across the year, and starting from the year 2003, the temperature has a continuous increasing trend. Likewise, SAI (Figure 4) displayed that increasing trend above the long term average annual temperature observed since 2003 and it is in agreement with Mann-Kendall's statistics test result, which discovered a significant increase in average annual temperature (Z_{MK}=5.04, significant at α = 0.001 level) in Table 22. As a result, the results concur with those of Thornton et al. (2014)'s countries in the world's tropical regions revealed an upward trend in the yearly average temperature.

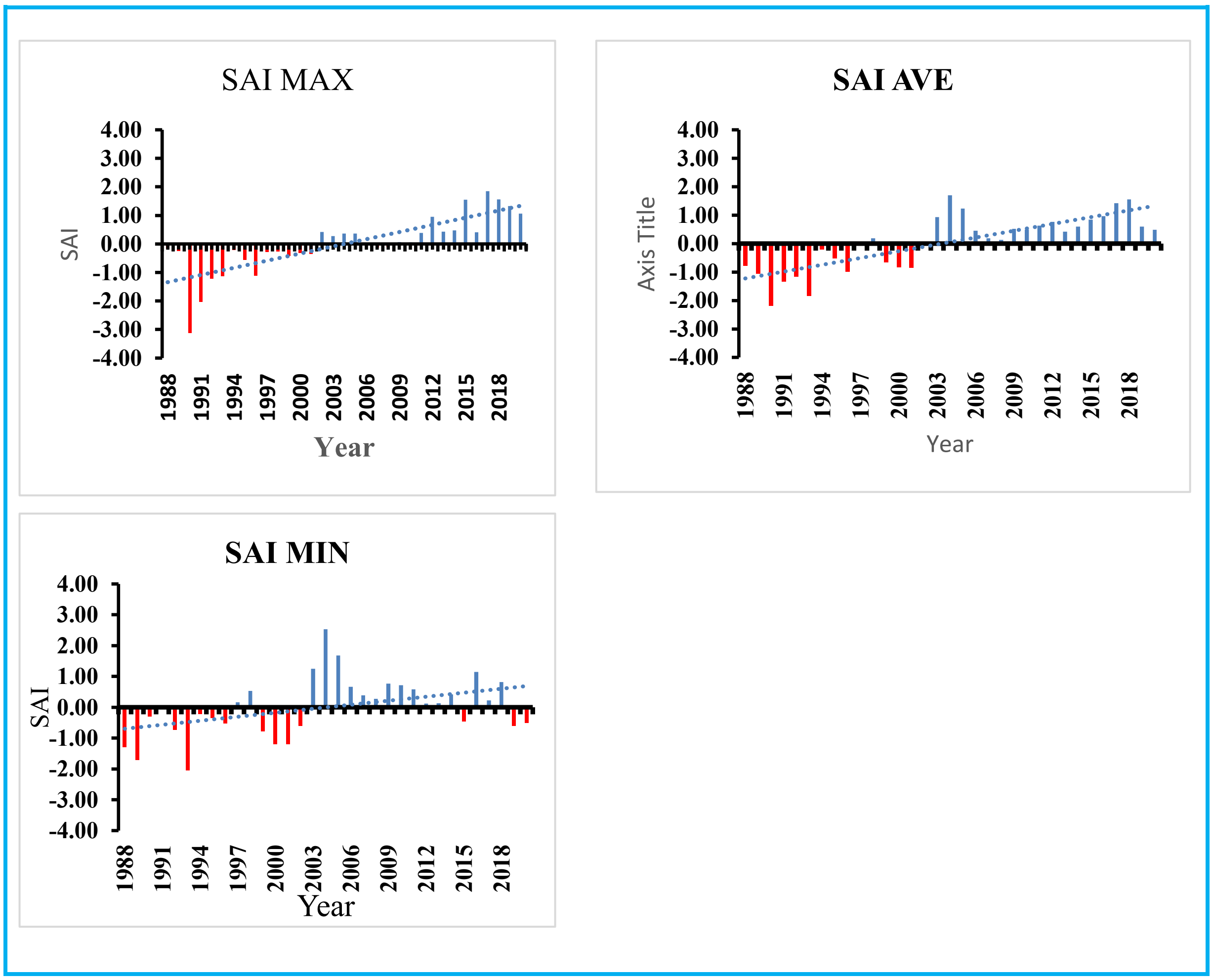

Figure 3: Standardized anomaly index (SAI) (1988-2020)
Source: EMI: Ethiopian Meteorology Institute (2022).

4.2.2. Trends of Rainfall

Ethiopia has a wide range of climates, ranging from semi-arid desert in the lowlands to humid and warm in the southwest, with mean yearly rainfall distributions ranging from >2000 mm in the highlands of Southwest to < 300 mm in the lowlands of south eastern and north eastern (NMSA, 2001). In Ethiopia, rainfall occurs at different times; however, the main rainy season is the Kiremt season, when there is a high likelihood of precipitation across much of the nation. Unlike the majority of the tropics, with one wet season, in Ethiopia there are three seasons: Bega (October–January), known as the dry season; Belg (February–May), known as a short rain season; and Kiremt (June–September), known as a long rain season in several regions of the nation (NMSA, 2001).

The yearly, Kiremt, and Belg season rainfalls of the study area (Table 22) imply increasing trend except for the Bega season, which has a decreasing trends of rain, however the result indicates not significantly increasing and the bega season also not significantly decreasing. The annual average rainfall during the last three decades was 1154.54 mm, with the highest record (1519.99 mm) during the year 2020 (Annex Table 6).

Table 22 Temperature and Rainfall Trends

Variables	Minimum	Maximum	Mean	Std.	Q/slope	Z_{MK}	Significance
Min. Annual Temprature	6.4	10.9	8.4	0.97	0.040	2.28	*
Max. Annual Temprature	20.2	26.1	23.9	1.20	0.091	5.66	***
Average Annual Temprature	14.1	17.6	16.1	0.87	0.070	5.04	***
Belg season Rainfall	75.51	369.60	230.37	77.28	0.191	0.07	**NS**
Kirem season Rainfall	640.09	1109.21	875.64	129.34	4.079	1.19	**NS**
Bega season Rainfall	11.75	106.13	48.53	27.87	-0.248	-0.27	**NS**
Annual Rainfall	864.30	1519.99	1154.54	173.53	3.667	0.95	**NS**

Note: *****,**,*** significant at **α=0.001, α=0.01, α=0.05 level,** and **NS=** Not Significant respectively

The study area's long-term hydrometeorology data show that the kiremt season rainfall contributes more than 75% for the annual rainfall on average, confirming that the kiremt season is the main source of precipitation (Annex Table 5).

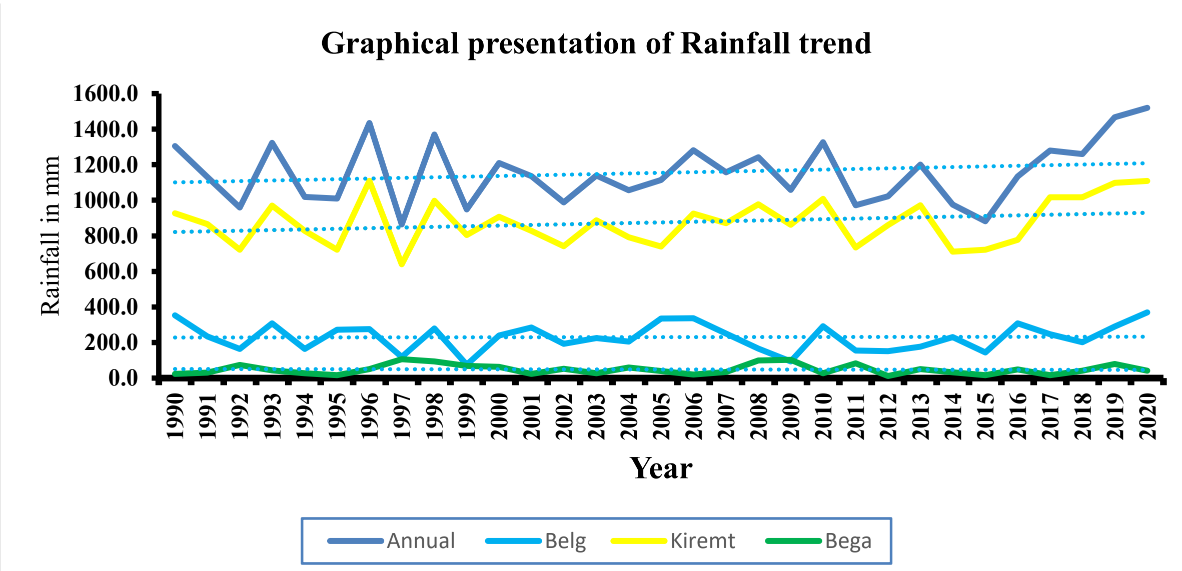

Figure 4: Rainfall Trend (Annual and seasonal)
Source: EMI: Ethiopian Meteorology Institute (2023).

The distribution of rainfall over three decades calculated and determined using precipitation concentration index. In the years 1994, 1999, 2009, 2012 and 2015 PCI result shows that rainfall distribution was strongly irregular. PCI in the others year 1990, 1991, 1992, 1993, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010, 2011, 2013, 2014, 2016, 2017, 2018, 2019 and 2020 shows, computed precipitation distribution result (Annex Table 6) reveals that irregular distribution.

Annual, Belg (small or short rainy season), Kiremt (wet season), and Bega (dry season) average mean rainfall was computed as 1154.54mm, 230.37mm, 875.64mm, and 48.53mm, respectively (Table 23). The computed coefficient of variation (CV) in Table 23 for the Belg and Bega seasons were 33.55% and 57.43%, respectively; this result implied there was high inter-seasonal variability for both the Belg and Bega seasons.

The annual and Kiremt (main wet season) rainfall computed CV results (15.03% and 14.77%) indicated less inter-seasonal and inter-annual variation in the order already mentioned.

Table 23 Rainfall variability of the study area

	Annual	Belg	Kiremt	Bega
Min	864.30	75.51	640.09	11.75
Max	1519.99	369.60	1109.21	106.13
Mean	1154.54	230.37	875.64	48.53
Stdev	173.53	77.28	129.34	27.87
CV	15.03	33.55	14.77	57.43

Source: Source: EMI: Ethiopian Meteorology Institute **(2023).**

Negative Rainfall anomaly in the last three decades from (1990 to 2020) observed many times during the bega season than both belg and kiremt season (Figure 6). Except in the bega season, no decreasing trend observed during the other rainy season (Figure 6). FGD result confirmed bega is the season when farmers suffer in search of feeds and enough water for livestock in contrast to the other seasons. This indicates that bega is the season that farmers in the study area faces shortages of rainfall and pasture for livestock comparatively to other season.

Annual Rainfall anomaly index (Figure 6), reveals in the last three decades from 1990 to 2020, the frequency displayed 14 years of rainy (positive RAI) and 17 years of dry (negative RAI) with varying degrees of intensity. The RAI result indicated, of the years viewed positive RAI, there are 3 years of highly humid, 4 years of very humid and 7 years of humid. However, among the 17 dry years (Figure 6), 1997 and 2015 were the years with the highest dry years with the negative RAI value -4.57 and -4.28 respectively.

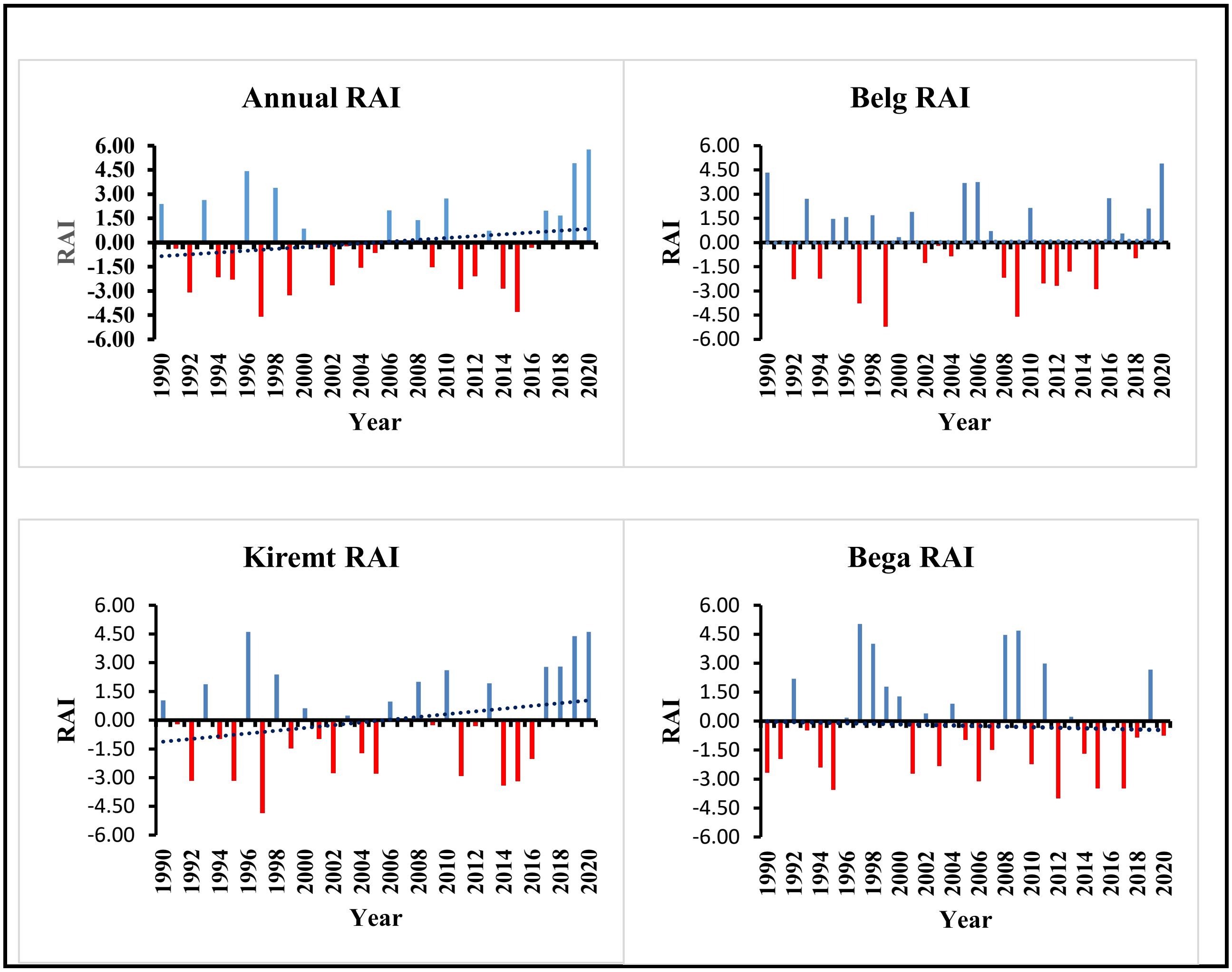

Figure 5: Rainfall Anomaly Index (RAI).
Source: EMI: Ethiopian Meteorology Institute (2023).

4.3. Farmers' perceptions of climate unpredictability and change

Climate change incidence and farmers' perceptions of climate change & variability are presented in this section. The variability and distribution of rainfall across different parts of the country have significant effect on production and productivity. The long-term meteorological data (Grid data of temperature and rainfall) of the last three decades from Ethiopian meteorology Institute indicated inter-seasonal and annual variability of rainfall and the temperature is rises significantly in the study area.

Climate change effects in the study area

Over the past thirty years, the study area has experienced incidents related to climate change and variability, which have had an effect on their way of living. According to the household survey report results, 203 respondent farmers (66.34%) responded, rainfall was erratic and late, unlike the time before 20 or 30 years. Flooding, which 60 respondents (19.61%) reported, was the other incidence because of climate change and variability observed in the area. This indeed affecting the crop production in the area. Once the top and fertile soil parts are removed, it affecting productivity and directly reduces the yield per plot of land. The other incidences from respondents are include high temperature, frost, and hailstorms by 25 (8.17%), 9 (2.94%), and 9 (2.94%) respondents, respectively. The FGD results and KII responses show that the onset of rainfall changes from year to year and becomes unpredictable, and their responses show that it is one of the primary obstacles in determining planting date (Table 24).

Table 24 Direct Climate Variability and Climate change consequences

Direct Incidences experienced related to Climate Change and variability	Freq.	Percent
Soil Erosion	60	19.61
Hailstorm	9	2.94
Late onset of rain	203	66.34
High temperature	25	8.17
Frost	9	2.94

Source: Survey data (May, 2022)

4.3.1. Climate Change Perception

To assess farmers' climate change and variability perception level, five-level Likert scale-based questions were used. Initially, 12 questions or items were prepared depending on the negative outcomes and concepts of climate change. From the 12 questions, 10 of them found to be reliable based on the result of Cronbach's alpha test (Cronbach's alpha > 0.7). To measure internal consistency or reliability between the questions or items, Cronbach's alpha was used (Mohamad et al., 2018).

Further examination of farmers' perceptions of climate change and variability reveals that the majority of farmers, 66.6%, strongly believe that the highest temperature has risen over the last three decades (Table 25). According to the outcomes of a household survey, 39.8% believed the weed problem is increasing. In total, 59.5% of respondents noticed a rise in the frequency of livestock disease occurrence, while 82.7% perceived an increase in crop disease occurrence.

The late onset of the main rainy season was perceived by 48.7% of the respondents, while the early offset (cessation) of rainfall was perceived by 63%. From overall respondents, 43.8% believed that the erratic nature of rainfall has increased, and 53.9% believed that water levels are dropping and water sources are disappearing.

Table 25 Extent of farmers Climate change and variability perception

Questions/Items, n=306	1=Very low	2=Low	3=Medium	4=High	5=very High	Mean (std.dev.)	Item test corr.	alpha
Increase day Temperature	0	5.2	28.1	53.9	12.7	3.74(0.74)	0.8	0.97
Increase night Temperature	24.5	19.3	31	25.2	0	2.57(1.11)	0.88	0.96
Erratic Nature of rainfall increased	10.5	20.9	24.8	30.7	13.1	3.15(1.20)	0.95	0.96
Invasive weed species increased	24.5	6.5	29.1	38.2	1.6	2.86(1.22)	0.93	0.96
Increase frequency of livestock disease	6.2	23.2	11.1	36.3	23.2	3.47(1.25)	0.73	0.97
Increase frequency of crop disease	0	5.2	12.1	37.3	45.4	4.23(0.85)	0.86	0.96
Onset of rainy season changed (late on set)	3.9	10.1	37.3	43.8	4.9	3.36(0.88)	0.8	0.97
offset of rainy season changed(early Cessation)	5.6	16	15.4	24.8	38.2	3.74(1.27)	0.97	0.96
Frost season frequency increase	14.7	0.7	32.7	29.7	22.2	3.44(1.26)	0.95	0.96
Disappearance of water sources	11.4	14.1	20.6	25.8	28.1	3.45(1.34)	0.93	0.96

Source: Survey data (May, 2022)

Model specification test

Multivariate probit model for CSA practices

Multivariate probit model is an appropriate model when the binary outcome variables are multiple. In this study, the outcome variables (Eight CSA practices) interdependently and jointly adopted Table 29. Multivariate probit model Wald chi2 (112) = 385.56, Prob > chi2 = 0.0001 demonstrates that all parameters the model contribute to the explanation of the dependent variable. The covariance of correlation matrix of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0 and the chi2 (28) = 251.988 Prob > chi2 = 0.0000 result indicate the correlation coefficients are all significant jointly. Hence, the null hypothesis which states no significant relationship between the error terms, is refused. Thus, MVP model is efficient for this analysis.

Ordered Logit regression

The chi-squared significant value of $p < 0.00001$ indicates that the model is fit that at least one of the explanatory variables influences farmers' perceptions of climate change. Biasness test, including the omitted variable test (OV-test), heteroscedasticity test, and multicollinearity test, which confirm that the result is free of biasness. The ordered logistic regression R^2 test result 0.196 indicate included regressors explained 20% of the model (Table 26).

Correlation Matrix

According to this, if there is a strong pair-wise correlation between two regressors, i.e., if the value is greater than 0.8, then multicollinearity is a major issue (Gujarati, 2003). From the result of the correlation matrix generated in STATA 16, no variables have multicollinearity problems (see appendix table 8).

Variance Inflation factor

To test for multicollinearity among explanatory factors, variance inflation factor$\left(VIF = \frac{1}{(1-r^2}\right)$ was tested. VIF indicates how the variance of an estimator is increased by the existence of multicollinearity (Gujarati, 2003). There is multicollinearity when VIF value approaches 10, and there is no multicollinearity as the VIF result approaches 1.

In this study, the VIF result is less than 10 with a maximum score of 2.84 and with a minimum score of 0.352 for the tolerance level (1/VIF) (appendix table 9). Stata 16 was employed to compute VIF.

Heteroscedasticity

It refers the absence of homoscedasticity or constant variance; in the other case, it implies the existence of unequal variance for each disturbance term conditional on the chosen explanatory factors value (Gujarati, 2003). The Breusch-Pagan test was used to check for heteroscedasticity in the data (Wooldridge, 2009). Since the p-value for the test result is insignificant, indicates that there is no heteroscedasticity problem.

4.3.2. Determinants of farmers climate change perception

Climate change Perception levels vary in terms of household age, education level, family size, farming system, land size, access to credit service and access to agricultural extension & training. This table used for indicate the model fitness while more discussion for relationship between determinant factors and perception level is based on the result in Table 27.

Table 26 Determinants of farmers Climate Change Perception Level

Log likelihood = -363.62		**Number of obs**	**= 306**	
		LR chi2(8)	= 160.46	
		Prob > chi2	= 0.0000	
		Pseudo R2	= 0.1808	
Perception level	**coef.**	**Std. Err.**	**z**	**P>z**
HHS	-0.059	0.319	-0.19	0.853
HHA	0.083***	0.014	6.09	0.000
education	-0.295**	0.122	-2.42	0.016
FS	0.212***	0.065	3.24	0.001
HHFS	0.897**	0.401	2.23	0.025
LS	0.348**	0.147	2.36	0.018
ACCS	1.096***	0.247	4.44	0.000
ACCAGRTR	1.388***	0.235	5.92	0.000
/cut1	4.517	1.47		
/cut2	7.049	1.471		
/cut3	8.725	1.499		
/cut4	11.185	1.554		

Source: Survey data (May 2022) Note: ***, **,*= significant at 0.01, 0.05 and 0.1 respectively

In ordinal logistic regression models, there is crucial assumption called the parallel lines assumption. According to this assumption, the effect of the factor variable on the categories of dependent variable is the same in each regression equation (Erkan and Zeki 2014). This assumption states that the explained variable's categories are parallel to each other. When the assumption is violated does not hold, it means that there are no parallel relation between categories (Erkan and Zeki 2014). We must therefore verify the model's parallel regression assumption first.

The parallel regression assumptions (Annex Table 7) were met, P-value of the test obtained by all methods is >0.1. Keeping all other variables constant, the marginal effect result computed in Table 27 was described compared to the base category. The marginal effect result indicates that, as household head age rise by one unit, there is a 0.1% decrease in the likelihood of being in a very low perception level, a 1% decrease in low perception level, a further 1% decrease in medium perception level. However, a 1.5% increase in high perception level, and a 0.6% increase in very high perception level.

The education level marginal effect result shows that as education level increases by one unit, from one educational cycle to the next (from first cycle primary education level grades 1-4 to second cycle primary education level grades 5-8), there is a 0.4% more likely to be in the very low perception level. Similarly, a 3.5% more likely to be in the low perception level, again a 3.5% more likely in the medium perception level. However, a 5.2% and a 2.1% less likely to be in the high perception level and in the very high perception level.

The other explanatory variable that predicted to cause variability in perception level among respondents was family size. As family size increases by one unit, a 0.3% less likely to be in the very low perception level, similarly 2.5% and 2.5% less likely to be in the low and medium perception level. However, as family size increases by one unit, there is a 3.8% and a 1.5% more likely to be in the high and very high perception level.

The marginal effect result shows that compared to households with only managing crop or livestock, those rely on both crop and livestock, a 1.3%, 10.6% and 10.5% less likely to be in the very low, low and medium perception level. However, a 15.9% and 6.5% more likely to be in the high and very high perception level.

Another explanatory variable that significantly affects respondents' perceptions of climate change is farmland size. The marginal effect result shows, a one-unit increase in land size decreases the probability in very low perception level, low perception level and medium perception level by 0.5%, 4.1% and 4.1% respectively. However, the result shows that as land size increase by one unit, there is a 6.2% and 2.5% more likely to be in the high and very high perception level respectively.

Financial resource is among the crucial resources for agrarian community to buy farm resources. Credit services are the means of getting this financial resource especially for the farmers have an interest to take and use it. The marginal effect result shows as credit service access increases said that from 0 to 1, the probability in very low perception level, in low perception level, and in medium perception level decreases by 1.4%, 11.7%, 13.5% respectively. Unlike to the three perception level, as credit service access increases said that from 0 to 1, a 17.2% and 9.4% more likely to be in the high and very high perception level respectively.

The result in Table 27 shows that as access to extension services & agricultural training increases said that from 0 to 1, a 2%, 16% and 15.3% less likely to be in the very low climate change perception level, low perception level and medium perception level respectively. To the contrary, as access to extension services & agricultural training increases said that from 0 to 1, a 22.4% and 11% more likely to be in high perception level and very high perception level of climate change respectively.

Table 27 Marginal Fixed Effect of Farmers Climate Change Perception Level

variable	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***
	1	**2**	**3**	**4**	**5**
*HHS**	0.001	0.007	0.007	-0.010	-0.004
HHA	-0.001***	-0.010***	-0.010***	0.015***	0.006***
educat~n	0.004**	0.035**	0.035**	-0.052**	-0.021**
FS	-0.003**	-0.025***	-0.025***	0.038***	0.015***
HHFS	-0.013*	-0.106**	-0.105**	0.159**	0.065**
LS	-0.005**	-0.041**	-0.041**	0.062**	0.025**
*ACCS**	-0.014***	-0.117***	-0.135***	0.172***	0.094***
*ACCAGRTR**	-0.020***	-0.160***	-0.153***	0.224***	0.110***

Variables with (*) indicates, dy/dx is for discrete change of dummy variable from 0 to 1
Significance level, * p<0.1, ** p<0.05, *** p<0.01

Farmers' perception of climate change differ from one another depending on institutional, social, and demographic factors. The majority of the respondent perceived increased daytime temperatures, increased livestock disease frequency, increased crop disease frequency (wheat rust), early cessation of rain, increased frost season frequency, and reduced water level and disappearance of water sources. Tropical regions around the world confirmed an upward trend in annual average temperature (Thornton et al., 2014). Maddison (2006) discovered an increasing trend in temperature in various African countries.

Climate change has an immediate and indirect impact on animal health. The direct effect of climate change is a rise in temperature, which has an impact on animal health; the indirect effect is that climate change creates favorable conditions for microbial and disease transmitters or vectors. Climate change causes drought in some areas while causing flooding in others because of heavy rain and other issues. Even though high temperatures caused by climate change may impede survivor and pathogen transmission into the host, climate change is the cause of flooding, which affects and creates a conducive environment for free-living pathogens and is the cause of animal disease transmission (Magiri et al., 2022; Rojas-Downing et al., 2017).

Respondents were certain that crop disease had happened frequently. Similar to the livestock disease, Climate change is likely to favor crop diseases such as stem rust. A higher temperature encourages the growth of several fungal species (Prank et al., 2019).

Climate change, which is likely to be the cause of rising global temperature, is projected to establish more appropriate circumstances for crop diseases and pest infestations (WBG, 2021). According to the statistical results in Table 25, 49% of respondents believed there was a delay in the start of rain during the main rainy or wet season. The outcomes of the study match up with the Diendere (2019) study done in Africa, Benin, which shows all respondents responded to the delay in rainfall time, and the study by Saguye (2017) done in Geze Gofa district, southern Ethiopia, which investigated the relative quantity of farmers' perceptions of the late onset and erratic nature of rainfall.

The statistical results in Tables 36 demonstrate that perceptions of climate change vary by age group. The marginal effect result indicates a higher likelihood of high and very high perception level. The study's outcome align with those of Saguye (2017), who claimed that farmers' perception levels positively and significantly affected by age. Ziadat (2010) discovered that respondents 50 years of age or older had a higher level of environmental awareness.

The findings in this study indicates that education level negatively influences the level of climate change perception. The likelihood of having higher perception level decreases as one's educational level rises. The result differs from the findings of Dagne et al. (2022) and Ziadat (2010), who investigated whether education cut down low and medium levels of environmental awareness while increasing higher levels of awareness. In this study, the more advanced in level of education, the lesser level of perception, which may reflect the fact that farmers rely more on their experience because the majority of respondents have low-level formal education.

Respondent farmers with large family members have high climate change perceptions. The marginal effect result shows, lower perception level decreases as family size increases. Farmers who practice both crop and livestock production farming concurrently have higher climate change perception than farmers who only practice crop production. Farmers who grow crops as well as manage livestock are conscious of climate change. One possible solution is that farmers with both farming system have access to communicate with different professionals and it may help them access diversified information compared to farmers with single farming activities (crop only or livestock only farming system).

Marginal effect result indicates the probability of being in higher perception level increases as farm size increases. The outcome lines up with the study's findings by Ochenje et al. (2016) which indicate farmers with larger plots of land believed that there was a greater loss of water resource owing to climate change effects on water resource than farmers with smaller plots of land.

4.4.Implementation of climate-smart agriculture practices in the study area

The negative effects of climate change are being seen in production and productivity. According to the survey data, FGD and KII, farmers believed that the rise in temperature and the late start of the main rain or wet season were indicators of climate variability. Soil erosion, hailstorms, late onset, high temperatures, and frost are the main incidences reported by respondents in the study area (Table 24). These incidences are affecting agricultural production and productivity, both directly and indirectly. In order to minimize the effects of climate change in the study areas, there are CSA practices implementing by farmers (Table 28). Based on these incidences, farmers are implementing various coping strategies (Jirata et al., 2016; Keller, 2009; FAO, 2013). Implementation of practices such as nitrogen-efficient and heat-tolerant or resistance crop varieties, zero-tillage

Table 28 CSA practices in the study area

		Kebeles						**Total % N=306**		
		Berfeta lemefa **n=66**		B/ Gaba Robi **n=105**		Berfeta Tokkofa **n=135**				
CSA practices	Practice component	Adopters	Non adopter	Adopters	Non adopter	Adopters	Non adopter	Adopter	Non Adopter	Aggregate
conservation Agriculture	Bund (soil or stone)	18.2	81.8	10.5	89.5	13.3	86.7	13.4	86.6	**42.5/57.5**
	Reduced Tillage	27.3	72.7	36.2	63.8	12.6	87.4	23.9	76.1	
	Crop residue management and mulching	25.8	74.2	37.1	62.9	23.7	76.3	28.8	71.2	
	Crop Rotation	36.4	63.6	54.3	45.7	32.6	67.4	41.8	58.2	
	Compost	47	53	22.9	77.1	20.7	79.3	27.1	72.9	

Integrated soil fertility manageme nt	Efficient fertilizer	33.3	66.7	26.7	73.3	32.4	67.6	27.5	72.5	61 /3 9
	Green Manure	78.8	21.2	75.2	24.8	43.7	56.3	58.8	41.2	
Small Scale Irrigation	Year round cropping	54.5	45.5	23.8	76.2	20.7	79.3	38	62	
	Efficient water utilization	21.2	78.8	10.5	89.5	5.9	94.1	10.8	89.2	
Agroforest ry	Tree based conservation Agriculture	18.2	81.8	20	80	16.3	83.7	33	67	38 /6 2
	farmers managed Natural regeneration	10.6	89.4	10.5	89.5	9.6	90.4	10.1	89.9	
Crop diversificat ion	high yielding, disease resistance and short season improved varieties	60.6	39.4	72.4	27.6	31.1	68.9	51.6	48.4	
Improved Livestock feed and feeding practices	reduced open grazing	15.2	84.8	33.3	66.7	22.2	77.8	24.5	75.5	39 /6 1
	forage development	16.7	83.3	44.8	55.2	29.6	70.4	36	64	
	feed improvement	25.8	74.2	42.9	57.1	16.3	87.7	27.5	72.5	
	livestock breed improvement	3	97	38.1	61.9	17.8	82.2	21.6	78.4	
Water harvesting		0	0	0	0	0	0	0	0	
Improved weather information system		48.5	515	34.3	65.7	37.8	62.2	38.9	61.1	
Livelihood diversification		9.1	90.9	3.8	96.2	3.7	96.3	4.9	95.1	
Post-Harvest technology		18.2	81.8	42.8	57.1	33.3	66.7	38.6	61.4	

or minimum tillage, and management of integrated soil fertility would boost productivity and farmers' earnings while also lowering food prices (FAO, 2016).

Adoption of CSA practices is likely vary from place to place due to the diversity of agro ecology and agricultural practices in Ethiopia. CSA practices that have the potential to minimize climate change effects include zero tillage (minimum tillage) and integrated soil fertility management (Komarek et al., 2018). A study by Saguye (2017) proves that agroforestry, soil and water management, crop management, and practices of livestock management are among the most commonly practiced CSA practices.

The research area has a low rate of implementation of CSA techniques. Conservation agriculture, management of integrated soil fertility, high yielding, disease resistance, and drought tolerance, short-season crop varieties (crop diversification) adopters' percentage indicate 42.5%, 61%, and 52%, respectively, while the other practices were adopted by less than 40% of respondents. The result shows, adoption rate of different CSA practices remains low in the study area. As compared to adoption level in some areas in Ethiopia, for instance, compared to Wondo Genet, Bamlaku and Abera (2022), the adoption of CSA practices in the study area including CSA practices like mulching, crop diversification, minimal tillage and tree planting is low except livestock breed improvement and use of green manure. The adoption of improved crop varieties and crop residue management & mulching in the study area is also at its lower levels when compared to the adoption level in Siyadebra Wayu district, Kifle et al., (2022).

The farmers are assume adopters of the practices for example conservation agriculture if the farmers adopt at list one of the component of the practice for example bund or reduced tillage or crop residue or crop rotation.

4.4.1. Climate smart Agriculture Adoption barriers

Respondent farmers who were surveyed responded that a variety of barriers make the adoption process challenging. Figure 7 depicts Climate smart agriculture practices adoption main challenges identified by farmers. Lack of technical knowledge for the CSA practices, lack of access to irrigation water, labor shortage peculiarly for laborious practices, lack of full information and lack of financial resources were the major impediments to CSA practice adoption.

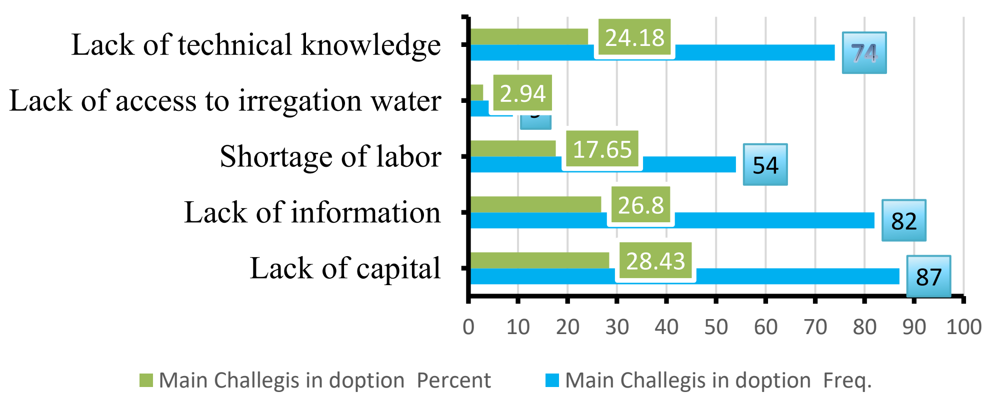

Figure 6: CSA adoption barriers
Source: Survey data (May, 2022)

According to a study by Titay et al. (2022), poor information access and limited financial resources are among the challenges confronting farmers and impeding the use of climate change adaptation strategies.

4.5.Interdependency of adopted CSA practices

The result of correlation coefficient error components accessed from the model (MVP) estimate of eight CSA practices indicated correlation coefficients are jointly significant. This confirms that the null hypothesis that there is no significant relationship between the error terms in all eight equations was jilted or rejected.

Table 29 Covariance of correlation matrix of CSA practices
Note: Stand.er. in parenthesis. ***,**,* significant at 0.01, 0.05, 0.1 in the order already

CSA practices relation	CSA practices relation	Corr. Coef.
Management of Improved soil fertility and Conservation Agriculture	rho21	**0.335***(0.074)**
Small Scale Irrigation and Conservation Agriculture	rho31	-0.056(0.080)
Agroforestry and Conservation Agriculture	rho41	-0.043(0.080)
Diversification of Crop and Conservation Agriculture	rho51	**0.204**(0.086)**
Improved Livestock feed& feeding and Conservation Agriculture	rho61	**0.192**(0.085)**
Improved weather information and Conservation Agriculture	rho71	-0.047(0.076)
Post-harvest technology and Conservation Agriculture	rho81	**0.898***(0.023)**
Small scale irrigation and Improved soil fertility	rho32	-0.110(0.079)
Agroforestry and Improved soil fertility	rho42	0.046(0.078)
Diversification of Crop and Improved soil fertility	rho52	**0.221**(0.084)**
Improved livestock feed & feeding and Improved soil fertility	rho62	**0.219**(0.087)**
Improved weather information and Improved soil fertility	rho72	0.051(0.077)
Post-harvest technology and Improved soil fertility	rho82	**0.398***(0.087)**
Agroforestry and small scale irrigation	rho43	**0.367***(0.062)**
Diversification of Crop and small scale irrigation	rho53	-0.036(0.082)
Improved livestock feed & feeding and small scale irrigation	rho63	0.006(0.088)
Improved weather information and small scale irrigation	rho73	0.081(0.069)
Post-harvest technology and small scale irrigation	rho83	0.018(0.089)
Diversification of Crop and Agroforestry	rho54	-0.103(0.085)
Improved livestock feed & feeding and Agroforestry	rho64	-0.021(0.093)
Improved weather information Agroforestry	rho74	0.067(0.075)
Postharvest technology and Agroforestry	rho84	0.022(0.095)
Improved livestock feed & feeding Crop diversification	rho65	0.102(0.099)
Improved weather information and Crop diversification	rho75	0.111(0.081)
Post-harvest technology and Crop diversification	rho85	**0.210**(0.096)**
Improved weather information and Improved livestock feed &feeding	rho76	-0.061(0.082)
Post-harvest technology and Improved livestock feed& feeding	rho86	**0.351***(0.097)**
Post-harvest technology and Improved weather information	rho87	-0.074(0.090)

mentioned

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0: chi2 (28) = 251.988 Prob > chi2 = 0.0000

Table 29 shows the interdependently and jointly adopted CSA practices by farmers. Moreover, it indicates that those practices are complementary. The outcome line up with the findings of (Abyiot et al., 2023; Mebratu et al., 2022; Samuel et al. 2022; Tamirat, 2022).

4.6.Adoption Factors for Climate Smart Agriculture practices

Adoption determinants of climate-smart agriculture practices were investigated using a multivariate probit model. Institutional, socioeconomic, and demographic factors are identified explanatory factors in the analysis result. Dependent variables are agricultural conservation practices, management of improved soil fertility, small-size irrigation, agroforestry practices, diversification of crop, improved practices of livestock feed & feeding, improved weather information, and post-harvest technology suppose 1 if the practice adopted by farmers 0 otherwise (**Table 30**).

The coefficient result of multivariate probit is shown in **Table 30** below. Independent variables are household head sex, age, family size, education level, climate change perception, farm land size, livestock holding (TLU), farm income, household farming system, credit service access, agricultural extension & agricultural training access and farmer field day participation.

Socio-demographic factors

Sex

Site and agro ecology specific improved crop varieties including drought and disease resistance, high yielding crop varieties are recommended to cultivate in the situation when climate change is affecting production and productivity to overcome the devastating effects of climate change on the agriculture. The outcomes of the research indicate that household sex or being male as compared to female significantly increased **($p<0.01$)** the likelihood of implementation of diversification of crop or improved crop varieties.

Livestock production is one sector of the agriculture which contributing for greenhouse gas emission specifically methane gas, hence working on livestock feed and breed improvement is crucial in this case. Household sex or being male as compared to female significantly increased **($p<0.1$)** the likelihood of adoption of practices of improved livestock feed and feeding.

Age

The level of soil fertility is one of the determining factors that potentially affect the output per plot of land in agriculture that is why many farmers encouraged adding fertilizer to their farmland. However, if farmland is failed to be managed in well-mannered, soil fertility is decreasing, possibly because of climate change and unwise use. In this study, the result indicated household head age significantly ($p<0.05$) and negatively influenced the likelihood of improved soil fertility practice adoption. This suggests that younger people are more motivated to implement improved soil fertility practices than the older. Possible explanation is that improved soil fertility practices for example compost and manure applications are laborious that more easily applicable for youngster than older. Likewise the age of household significantly ($p<0.05$) and negatively affecting crop diversification. This outcome matches up with the findings of (Mebratu et al. 2022).

Household head age is positively and significantly affected the implementation of agroforestry ($p<0.05$). The outcome is parallels with Abyiot et al. (2023), which indicated age is significantly and positively affected agroforestry practice implementation.

Education level

Agroforestry practices, such as tree-based conservation agriculture can help lessen climate change consequences. Trees and other plants can reduce erosion. The study result indicated, level of education significantly ($p<0.1$) and positively affecting adoption of agroforestry practice. The result is parallel with Abyiot et al. (2023).

Climate change Perception

Climate change perception believed to have significant and positive contribution for CSA adoption in this study. It has significantly ($p<0.05$) increased improved weather information adoption. This implies that as perception of climate change develops the decision to use improved weather information increases.

Economic factors

Land holding

Households land holding size significantly ($p<0.01$) increased adoption decision of agroforestry practices. The findings is parallel with the study output by Samuel et al. (2022), who found that adoption of minimum tillage (agricultural conservation practices) was substantially and favorably influenced by total land holding and Tamirat (2022), who found that adoption of conservation tillage significantly and positively influenced by cultivated land size owned by households.

Management improved soil fertility practice is significantly ($P<0.01$) and positively influenced by size of farmland. Likewise, diversification of crop significantly and positively influenced by size of farmland. This could mean that farmers who have larger farms are more apt to allocate farmland to various improved crop varieties than farmers who have smaller farms.

Improved livestock feed and feeding practice is significantly ($p<0.01$) and positively influenced by households land holding size. This implies households relatively with large farmland sizes more likely to adopt improved livestock feed and different forages for livestock feed compared with households relatively small land holdings. Post-harvest technologies are a measure taken after harvest of a product for conserving, protecting or processing. The study result indicated that land holding size significantly ($p<0.01$) increased the probability of adopting post-harvest technology practice.

Farm income

Households farm income significantly ($P<0.01$) and positively affected improved livestock feed and feeding practice adoption. This indicated that as farmers' income increases the likelihood of adopting improved livestock feed and feeding practices.

Credit service access

The result indicated that farmers who have credit access more likely to adopt practices of agroforestry than farmers who have no access to credit services. The possible explanation perhaps agroforestry practices requires getting different seedlings of trees that have dual advantages both for conserving the soil and for producing fruit. Such tree seedlings may be expensive to purchase, but many people lack financial resources, and in this case, access to credit services helps to secure the gap. The analysis result also indicated that, diversification of crop or improved crop varieties adoption significantly ($p<0.05$) and positively affected by credit services access. The possible explanation is that improved seed and inputs related with the seed requires cash, which may not possible for every smallholder farmers to have at hand during the required time. Thus, credit services access probably helps farmers to secure this gap. Likewise post-harvest technology adoption significantly and positively ($p<0.05$) related with access to credit service. This implies that farmer who have credit service access more likely to implement practices of post-harvest technology than farmers who have no credit service access.

Livestock holding

Livestock is the basic and important asset in rural parts of Ethiopia and helps the smallholder farmers for many including as a source of income and use the livestock product for household consumption and sources of cash. The result indicated livestock holding size significantly and positively ($P<0.05$) influenced adoption of conservation agriculture. The result is parallel with the study output of Tazeze et al. (2012); Samuel et al. (2022), which confirms that an increase in livestock holding increases the probability of adoption of soil and water conservation techniques. To the contrary, livestock holding significantly and negatively ($P<0.01$) affected the likelihood of adoption of small-size irrigation practice. The result is parallel with the study result of Titay et al. (2022), which found that livestock and small-scale irrigation could compete for water. Likewise, livestock holding and adoption of agroforestry practices are significantly and negatively related. As livestock holding size increases, the possibility of adopting agroforestry practices drops. The FGD result reveals that extensive livestock management is one of the challenge for tree-based conservation or planting trees in the field. Animals feed on the seedlings and harm them; as a result, the seedling cannot thrive if it is not protected from the animals.

Table 30 Determinants of implementation of CSA practices

Variables	Conservation Agriculture	Improved soil fertility	Small scale irrigation	Agroforestry practices	Improved crop/Crop diversification	Improved Livestock feed and feeding	Improved weather information	Post-harvest technology
Sex	0.035	0.154	-0.018	-0.141	**0.887*** **	**0.553***	-0.156	0.27
	(0.277)	(0.226)	(0.235)	(0.226)	**(0.273)**	**(0.311)**	(0.222)	(0.252)
Age	-0.206	**-0.264** **	0.152	**0.282** **	**-0.316** **	-0.018	0.149	-0.180
	(0.155)	**(0.125)**	(0.118)	**(0.119)**	**(0.140)**	(0.130)	(0.119)	(0.123)
Education Level	-0.155	-0.083	0.057	**0.208***	**-0.273**	0.121	0.010	-0.19
	(0.135)	(0.108)	(0.109)	**(0.107)**	**(0.133)**	(0.122)	(0.107)	(0.111)
CC Perception level	-0.043	0.084	0.027	0.0014	0.192	0.267	**0.36** **	0.005
	(0.194)	(0.147)	(0.143)	(0.143)	(0.167)	(0.174)	**(0.144)**	(0.167)
Family size	-0.038	0.049	-0.094	0.064	-0.028	-0.001	0.103	-0.056
	(0.266)	(0.206)	(0.207)	(0.206)	(0.23)	(0.260)	(0.200)	(0.254)
Farm land size	**1.919*** **	**0.578*** **	0.221	-0.064	**0.840*** **	**1.120*** **	-0.080	**1.611*** **
	(0.234)	**(0.162)**	(0.154)	(0.153)	**(0.18)**	**(0.204)**	(0.151)	**(0.193)**
Farming system	-0.167	0.389	-2.383	**-0.278**	0.174	1.916	-0.021	-0.39
	(0.364)	(0.296)	(50.206)	**(0.348)**	(0.319)	(74.25)	(0.299)	(0.283)
Farm income	-0.0052	-0.0009	0.00062	0.0011	-0.0021	**0.034*** **	0.005	**-0.009**
	(0.0057)	(0.004)	(0.0049)	(0.005)	(0.005)	**(0.0061)**	(0.0045)	**(0.005)**
Credit Service Access	0.158	-0.253	**0.221**	**0.417** **	**0.67** **	-0.018	-0.046	**0.43** **
	(0.235)	(0.186)	**(0.176)**	**(0.175)**	**(0.215)**	(0.218)	(0.179)	**(0.213)**
Livestock Holding	**0.121** **	0.004	**-0.147*** **	**-0.073***	-0.016	-0.072	0.014	**0.13**
(TLU)	**(0.047)**	(0.038)	**(0.040)**	**(0.038)**	(0.041)	(0.044)	(0.037)	**(0.040)**
Access to Agri. Ext.	-0.029	-0.037	-0.0221	-0.367	**1.212*** **	**-0.241**	0.067	0.0755
services & agri. training	(0.292)	(0.230)	(0.235)	(0.237)	**(0.258)**	**(0.29)**	(0.225)	(0.248)
Field day Participation	**0.504***	**0.664*** **	**0.256**	0.24	0.405*	-0.146	-0.263	**0.296**
	(0.265)	**(0.128)**	**(0.123)**	(0.23)	(0.236)	(0.254)	(0.213)	**(0.134)**
Cont.	-2.517	-1.429	6.497	0.449	-2.64	-10.79	0.67	-2.00
	(1.256)	(1.056)	(150.62)	(1.192)	(1.146)	(222.7)	(1.07)	(1.043)

Log likelihood = -1144.4475

Wald chi2(112) = 385.56

Prob > chi2 = 0.0000

Note: Stand.er. in parenthesis *,**,* significant at 0.01, 0.05, 0.1 in the order already mentioned**

Institutional factors

Agriculture extension services& trainings Access

Agricultural extension services and agricultural trainings, the methods and means through which farmers' access different agricultural information significantly ($p< 0.01$) and positively affect the implementation diversification of crop. The study result much up those of (Abyiot et al., 2023 and Mebratu et al., 2022).

Farmers' field day participation

Field days are an important component of the farmer's field school approach, which takes place at the end after trainings are carried out to inform and explain the demonstration to a larger group of farmers and it is an approach being practiced in more than 90 countries (Emerick and Dar 2021). The study result indicated that farmers field day participation significantly ($p<0.1$) and positively affect adoption of conservation agriculture practices similarly it affects the adoption of crop diversification positively ($p<0.1$) and significantly. This implies that farmer's access to participate in the field day occasion more inclined to practice agroforestry and different crop varieties compared to the farmers who have no access to participate on field day. Similarly, farmers who have access to participate in field day more inclined to adopt management of integrated soil fertility.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1.Conclusion

The research looks into climate change perception, adoption, and determinants of climate smart agriculture in the Welmera woreda, Oromia region, Ethiopia. Farmers' perception toward climate change vary according to their age, education level, family size, farming system and farmland size. Accordingly, Farmers' climate change perceptions' level is positively and significantly influenced by household head age, size of family, farming system and farmland size. However, educational level negatively affects climate change perception.

The majority of respondent farmers have awareness about climate-smart agriculture practices; however, the study findings indicate that CSA practices are not widely used in the study area. Conservation agriculture, integrated soil fertility management practices, small-scale irrigation, agroforestry practices, crop diversification, improved livestock feed and feeding practices, improved weather information and postharvest technologies are identified CSA practices being implemented by respondent farmers; the rate of adoption, however shows that many of the practices are still in the early phases of adoption.

The findings of study imply that there are multiple factors influencing adoption of CSA practices. Based on economic constraint model, having relatively large farm land size significantly increases the adoption of conservation agriculture, management of improved soil fertility, diversification of crop, practice of improved livestock feed and feeding, and postharvest technology practice. Better farm income raises the likelihood of uptake of improved livestock feed and feeding. Having a large number of livestock positively influences adoption of conservation agriculture and having access to credit services positively influences the implementation of agroforestry, crop diversification, and postharvest technology. In addition, innovation diffusion model indicated agricultural extension and training access positively influences the adoption of crop diversification, access to participation on farmers' field day similarly positively influence the adoption of both conservation agriculture and management of improved soil fertility practice.

The analysis of rainfall and temperature trends reveals an increase in temperature in the studied area. Temperature trends at both the minimum and maximum point to a clear rising trend. The outcome, however, shows that there has been no clear trend in the study area's rainfall during the past three decades, either in terms of an increase or reduction.

5.2. Recommendation

The findings demonstrate that signals of climate variability and change include rising temperatures and uneven rainfall over time. Overall, CSA practice adoption at the study site is still in its early stages, showing the necessity of awareness creation for farmers and experts at all levels about the significance of a campaign to improve the public's understanding and perception of climate change.

To increase the level of CSA practice adoption, improvements must be made to the accessibility of credit services, agricultural extension, agricultural training, and field day involvement, as the study's findings show that having comparatively better access to the aforementioned institutional services increases the likelihood that CSA practices will be adopted. Likewise, the farmer’s response indicated that many of the barriers to CSA practice adoption could be overcome by institutional services.

In order to hasten adoption, location-specific CSA practices ought to be included in the agricultural program. Policy makers and concerned bodies must pay close attention to the issues influencing agricultural extension and training system since this is an important factors. Researchers, decision-makers, and stakeholders must consider site-specific CSA practices to lessen the detrimental effects of climate change on agriculture.

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ANNEXES

Annex 1. Household survey Questionnaire

Questionnaire No._______________

CLIMATE CHANGE PERCEPTION, ADOPTION AND DETERMINANTS OF CLIMATE SMART AGRICULTURE

THE CASE OF WELMERA WOREDA, OROMIA REGION, ETHIOPIA.

Enumerators Name____________________

PART – I

OVERALL INFORMATION

Date _________________

Respondents name: ______________________________

Region: ____

District: ____

Kebele: ____

Phone number: ___________________

Agro ecology: 1. Highland 2. Midland 3. Lowland

PART – II RESPONDENTS DEMOGRAPHIC INFORMATION

1. Household head sex: 1. Female 2. Male

2. Household head age: _________________years

3. HH head marital status: 1. Single 2. Married 3. Divorced 4. Widowed 5. Polygamous

4. HH size: Male _______Female ________Total _______

All family members Age (in years). 10 – 17 ____. 18 – 35_____ 36 – 64 ______. $\geq$ 65 ______

5. Religion: 1. Orthodox 2. Protestant Christian 3. Muslim 4. Catholic 5. Other

6. Level of Education: 1. Unable to read and write 2. Attended Grade 1-4 3. Attended Grade 5-8 4. Attended Grades 9 -10 5. Attended Grade 11-12 6. TVET and above

PART – III ECONOMIC AND SOCIAL FACTORS

7. Household overall farm land size _____________________hectares

Own__________ Rented in___________ Rented Out__________

8. The farmland terrain 1. Plain 2. Hilly 3. Steep

9. Farmland fertility level : 1. Fertile 2. Moderately fertile 3. Less fertile 4. Infertile

10. HH agriculture experience in years___________________________________

11. Do the household access irrigation water? 1. Yes 2. No

12. If yes for question no.11, what is the size of field with irrigation water? _______Ha. / timad

13. Types of crops irrigated _____________________________________

14. Source water for irrigation? _______________________________

15. Production and consumption data for household crops (2013/14 cropping season)

No	Type of crop	Land Size	Amount in Quintals					
			Production 2013/14	Quantity Sold	for Seed	Set apart for Consumption	loss after harvest	
1	Wheat							
2	Barley							
3	Teff							
4	Maize							

5	Sorghum							
6	Pulses							
7	Oilseeds							
8	Vegetables							
9	Others							

16. Household Livestock data

No	Livestock type	Number
1	Local breed cow	
2	Cross breed cow	
3	Oxen	
4	Heifers	
5	Horse	
6	Mule	
7	Donkey	
8	Sheep	
9	Goat	
10	Poultry	
11	Bee colony	

17. Household farming/agriculture system

1. Producing Crop
2. Livestock management
3. Both livestock and crop production

18. Sources of income

1. Income from crop sale 2. Income from livestock 3. Income from both crop and livestock 4. Crop, livestock and off-farm

19. Annual income

No.	Income source from	Amount in ET. Birr	Remark
1	Sale of Crop		
2	Sale of Livestock		
3	Sale of Livestock product		
	Butter		
	Milk		
	egg		
7	Income from Off farm activity		
8	Remittance		
9	Others		
Total			

20. Do you employ the next techniques on your farmland?

No.	Activities	Yes	No
1	cultivating various crops (crop diversification)		
2	Cultivating different varieties of crops		
3	Using improved seed		
4	Changing the cropping practice and crop sowing date (early or late sowing)		

5	Cultivation of drought-tolerant plants		
6	Techniques for conserving water and soil		
7	Switching to non-farm activities		
8	Tree Planting		
9	Use of irrigation water		
10	Use of chemical fertilizer		
11	Use of compost/manure		
12	Use of BBM technology		

21. Types of improved crop seed you used during the last crop season for different,
Kg. /ha________________________, ________________________,
_______________________, _____________________________,
________________________, _______________________

22. How much fertilizer you used for the last cropping season?
DAP. _______Qt. Urea________Qt/hec. NPS_______Qt/hec. Total Fertilizer_________Qt.

23. Do you have off-farm income? 1. Yes 2. No

24. If yes for no.23, what type of off-farm income?

No.	**off-farm income sources**	**Birr/year**	**Total**
1	Employee part time		
2	Firewood sale		
3	Charcoal		
4	Remittance		
5	Others		

25. Farm input expenditure

Input type	**Did you use in 2013/14**	**Source**		**Amount bought**	**Unit Price**	**Total price**
		Purchase	**Aid**			
Fertilizer				Kg.		
Seeds				Kg.		
Herbicides (Different types)				Lit.		
Pesticides (Different types)				Lit.		
Livestock Feed				Kg.		
Inputs for Livestock treatment						

26. How do you judge productivity based on your experience?
1. Increased 2. Declined 3. Remained unchanged

PART-IV INSTITUTIONAL VARIABLES

27. In the past one year, have you had access to credit services? 1. Yes 2. No

28. If yes for No. 27, what was the loan used for?
1. Buy agricultural inputs (seed, fertilizer, pesticides, herbicides etc.)
2. Purchase land 3. Purchase livestock 4. Purchase farm inputs 5. Labor cost
   6. Rent land 7. If other ________________

29. Do you communicate with an agent for agricultural extension? 1. Yes 2. No
30. If yes for No.29, How often do you interact with agricultural extension agent in a year? _
31. Do you participate on farmer's field day? 1. Yes 2. No
32. What is the distance between your farm and the closest market? Km.___________
33. Do you have frequent access to weather information? 1. Yes 2. No
34. Have you had any training in agriculture? 1. Yes 2. No

PART-V INFORMATION ABOUT CLIMATE CHANGE

35. Would you think that climate change has occurred in the previous 20-30 or more years?
1. Yes 2. No

No	**To what extent you perceive climate change in your area for the last 30 years** **As compared with the last 20-30 years**	Current 1. Yes 2. No	How much do you agree? **1**. Strongly disagree **2**. Disagree **3.** Neutral (unchanged) **4.** Agree **5.** Strongly agree
	Increased daytime temperature		
	Increased nighttime temperature		
	Invasive weed species increased		
	Increased frequency of Heat induced livestock disease		
	Crop disease occurrence(Frequency) e.g. wheat rust		
	Onset of rainy season changed (late onset)		
	Frost season frequency increase		
	offset of rainy seasons changed (early offset)		
	Erratic Nature of rain fall		
	Decreasing and Disappearance of water sources		
	Early in planting time		
	Late in planting time		

36. What incidence you experienced related to climate changes in the last 20 or more years?
1. Drought 2. Flooding/Erosion 3. Hailstorm 4. Early onset 5. Late onset 6. High Temperature 7. Very cold temperature/Frost 8. Crop disease like wheat rust

37. Have you altered or change your farming techniques because of the negative incidents?
1. Yes 2. No

38. Do you know what climate-smart agriculture is? 1. Yes 2. No
39. Did the family member receive climate smart agriculture related training/information in the last year? 1. Yes 2. No
40. Which of the following climate smart agriculture practices you are adopting?
40.1. Conservation agriculture **1=No, 2=Yes**

Practices	**1=No,2=Yes**	Plot covered in kert(1kert=0.25hectare)

Bund (soil or stone)		
Lower Tillage		
Managing crop residue and mulching		
Rotation crop /intercropping		

40.2. Holistic soil fertility control/management 1**. Yes** **2. No**

Practices	**1=No, 2=Yes**	Plot covered in kert
Compost		Kg. _______
Manure (dry, green)		Kg. _______
Efficient fertilizer application		Kert______

40.3. Irrigation **1=No 2=Yes**

Practices	**1=No 2=Yes**	Plot covered in kert
cropping all year long		
Efficient use of water		

40.4. Agro-forestry 1=**No 2=Yes**

- Tree-based conservation agriculture **1=No 2=Yes**
- Farmer-managed natural regeneration **1=No 2=Yes**

40.5. Crop diversification **1=No 2=Yes**

Practices	**1=No 2=Yes**	Plot covered in kert
Popularization of new crop varieties		
High yielding variety, Disease resistance variety, Drought Tolerant variety		

40.6. Improved livestock feed and feeding practices **1=No 2=Yes**

Practices	**1=No 2=Yes**	**Plot covered in kert**
Decrease open grazing		
Forage development		
Improvement of livestock feed		
Animal breed development		

40.7. Water harvesting **1. Yes 2. No**
40.8. Improved weather information **1. Yes 2. No**
40.9. Livelihoods diversification (apiculture, aquaculture) **1. Yes 2. No**
40.10. Post-harvest technologies (storage) 1**. Yes 2. No**

41. What are the primary obstacles to implementing the aforementioned strategies? 1. Lack of enough money 2. Insufficient information 3. Inadequate labor 4. Inadequate water 5. Lack of technical knowledge 6. Other (specify)____

42. What are your primary sources of information regarding climate change? 1. Radio 2. Officers of extension services 3. NGO 4. Relatives 5. TV 6. Other farmers

43. How would you rank the availability of information about climate change? 1. Low 2. Medium 3. High

44. What determinant factors hinder climate change perception? 1. Lack of information 2. Poor communication with DA 3. Distance from market 4. Low information 5. If other_________________

45. How do you keep the feed for your animals? 1. No conservation practice 2. Hay storage/crop residue 3. Silage making 4. Other ________________________________

46. Do you now manage the livestock waste from your farm from the previous year? **1. Yes 2. No**

47. If Yes for No.46, How do you handle the waste or manure that your animals produce? 1. Cover under pit 2. Gather in the shade. 3. Gather uncovered in the open 4. Compost make 5. Throw away 6. Other _______________________________

Annex2. Key informant Interview (KII) checklist

Name of the respondent____________________Position___________________

Organization_________________________ Age___ Phone Number ______________

1. What do you believe about climate change and variability? _______________________
2. Types of challenges do you face because of climate variability and climate change?____
3. What do you think about climate smart agriculture?__________________________
4. What challenges did you have when putting CSA practices into practice?____
5. What is your perception of climate change adaptation?______________________
6. What factors are affecting crop production in your area?_______________________
7. What is climate variability you observed?_________________________________
8. What CSA practices you are adopting? (Conservation agriculture, Comprehensive soil fertility management, Irrigation on small-scale, Agroforestry, Diversification of Crop, Improved feed and feeding practices and if other) ____
9. What traits of improved varieties you prioritize for selection?______________________
10. What are the difficulties with the region's crop and livestock production and what do you think the causes for the challenges?____
11. Practically who are responsible for organizing different CSA practices implantation (Government, NGOs or community by themselves)? __________________________
12. What do you think about the care and sustainability of conservation practices so far implemented in this location? ____

Annex Table 3: List of questions to be addressed in focus group discussion

General Information

I. Region____________ II. Woreda____________ III. Kebele_____________

1. Do you believe that there is climate change and variability? What are the characteristics for the happening of variability and climate change?
2. What impact does climate change have on crop production and on agriculture in general? What do you think about reducing emissions and adaptation?
3. What kind of climate change adaptation strategies or CSA technologies do you use? What steps may be taken to increase the adoption of these climate-smart practices?

4. What incidences related to climate change in the area observed during the last decades? (hailstorm, drought, flood, extended dry period, late-setting rains, early cessation of rain, the season's temperature has risen
5. What makes difficult/determinants of adopting CSA practices/technologies?
6. What are the primary obstacles to the production of crops and livestock?
7. What new or climate-smart farming techniques are being promoted in the region/localities for crops and livestock?
8. What are the main crops in the localities/kebeles? List improved varieties of these crops. What do you think the adoption rate/extent is currently? What made them want to adopt?
9. How do you perceive the adoption of these crops with the changing climate condition?

Your opinion regarding the care and sustainability of conservation practices so far implemented in this location?

Annex Table 4: Conversion Factors Tropical Livestock Unit (TLU)

Types of Livestock	Conversion rates/Factors
Cows	1
Oxen	1
Bulls	1
Heifers	0.75
Calves	0.4
Sheep	0.1
Goats	0.1
Donkeys	0.5
Horse	0.8
Chickens	0.013

Source: Freeman, et al. 1996

Annex Table 5: Average annual, seasonal rainfall and the three seasons average rainfall contribution for annual rainfall in the last three decades

Year	Ave.Annual rainfall mm	Ave.Belg	Ave. Kiremt	Ave. Bega	Contribution of Belg rtainfall for annual rainfall (%)	Contribution of kiremt rainfall for annual rainfall (%)	Contribution of Bega for annual rainfall (%)
1990-2020	1154.5	230.37	875.64	48.53	19.95	75.84	4.20

Annex Table 6: Average monthly and annual rainfall distribution and PCI

Year	Jan	Feb	Mar	Apri	May	June	July	Augest	Sept	Oct	Nov	Dec	Annual	PCI
1990	1.9	198.6	29.5	99.5	26.1	111.4	314.4	354.1	148.0	18.9	1.3	1.9	1305.6	18.2
1991	7.6	60.9	119.7	10.2	43.8	130.8	319.9	276.9	138.2	4.6	0.3	17.9	1130.8	18.4
1992	21.9	26.8	32.7	52.2	51.5	103.6	242.7	274.5	101.5	43.0	4.4	4.3	959.2	17.9
1993	18.0	61.9	13.0	147.9	84.9	145.6	292.0	349.1	183.8	24.4	0.1	1.6	1322.2	16.9
1994	0.5	1.0	54.1	54.3	55.0	157.5	339.3	222.6	109.1	0.4	25.1	0.4	1019.4	20.3
1995	1.1	36.6	33.0	134.8	67.8	76.5	289.6	265.4	91.1	5.1	0.7	8.8	1010.5	19.0
1996	44.4	4.2	108.9	61.5	100.7	245.7	378.6	345.6	139.2	4.4	1.1	0.7	1435.1	18.0
1997	18.6	0.0	15.5	75.7	26.9	125.8	250.2	181.8	82.2	36.9	50.1	0.6	864.3	17.3
1998	41.4	63.4	49.3	43.2	122.7	160.6	358.2	331.2	146.6	45.3	4.5	3.1	1369.6	16.7
1999	6.5	1.7	20.3	11.5	42.0	149.3	294.8	281.7	78.5	62.0	0.1	0.3	948.7	22.3
2000	0.3	0.0	5.1	114.7	119.9	132.2	304.2	298.6	171.7	23.2	23.1	16.5	1209.5	17.6
2001	4.2	3.0	127.2	32.5	121.7	179.0	327.0	233.9	87.7	17.8	0.2	1.2	1135.2	18.1
2002	30.6	29.5	72.1	42.9	48.5	144.4	307.3	232.9	56.7	2.8	0.0	19.8	987.4	18.9
2003	6.2	71.1	56.9	83.6	13.1	155.7	342.7	253.2	136.4	5.4	3.4	12.0	1139.8	18.5
2004	18.1	13.9	42.6	128.4	20.6	152.4	263.2	235.5	140.6	39.4	1.2	0.2	1055.9	16.9
2005	14.5	5.8	80.9	99.6	148.9	113.5	252.7	247.4	126.7	18.2	6.7	0.0	1115.0	15.5
2006	1.5	45.2	120.9	81.5	89.3	149.7	381.4	261.7	131.7	10.8	0.5	7.1	1281.4	17.4
2007	17.1	19.3	52.0	69.5	109.8	220.3	251.4	280.2	120.1	17.1	0.3	0.3	1157.2	16.8
2008	0.9	8.1	8.3	43.3	106.5	154.5	358.5	318.1	145.8	31.9	66.7	0.2	1242.7	19.0
2009	24.2	3.6	38.3	20.9	31.2	85.6	322.7	337.5	116.8	43.4	4.1	30.4	1058.6	21.9
2010	4.7	56.8	68.4	75.0	91.1	186.1	406.4	244.9	170.7	4.4	6.1	12.7	1327.2	17.7
2011	6.3	6.3	43.9	19.3	85.8	118.8	181.4	296.7	136.9	0.6	67.3	8.5	971.8	17.8
2012	0.0	0.0	17.9	91.5	41.7	92.3	350.6	259.7	157.8	1.2	3.3	7.2	1023.3	22.4
2013	9.8	5.9	30.7	69.3	71.4	119.6	306.8	347.3	199.2	36.2	4.6	0.4	1201.3	19.5
2014	2.3	31.8	23.4	41.8	134.3	66.4	266.8	233.6	143.7	28.6	1.8	0.3	974.8	18.2
2015	0.0	4.1	10.6	5.3	125.0	122.3	226.2	256.6	116.3	3.7	6.4	6.3	882.7	20.7
2016	29.6	6.2	35.7	109.7	156.7	129.9	338.8	207.0	102.3	8.6	10.0	0.2	1134.7	17.4
2017	0.0	65.3	27.1	34.9	119.3	73.4	358.5	311.5	273.0	14.9	1.5	0.0	1279.6	19.9
2018	2.4	34.6	30.7	54.2	82.7	271.8	346.9	316.7	82.2	18.3	19.7	0.3	1260.5	19.8
2019	0.0	7.4	27.2	135.7	120.0	206.1	390.1	273.8	227.6	29.2	45.5	4.3	1467.0	16.6
2020	0.8	2.4	94.9	133.5	138.8	175.8	395.0	327.8	210.2	36.5	2.9	1.4	1520.0	16.7
Mon. Sum	335.5	875.2	1490.8	2177.8	597.7	4456.7	9758.4	8657.4	4272.2	637.3	362.9	168.7		
Mon. Mean	10.8	28.2	48.1	70.3	83.8	143.8	314.8	279.3	137.8	20.6	11.7	5.4		
on.Max	44.4	198.6	127.2	147.9	156.7	271.8	406.4	354.1	273.0	62.0	67.3	30.4		
on.Min	0.0	0.0	5.1	5.3	13.1	66.4	181.4	181.8	56.7	0.4	0.0	0.0		
TDEV	12.6	39.6	35.0	41.2	41.7	48.0	54.4	45.8	47.0	16.4	19.3	7.4		
CV	116.4	140.1	72.8	58.6	49.8	33.4	17.3	16.4	34.1	79.9	165.0	136.1		

Annex Table 7: Parallel regression assumption test

Tests	Chi2	df	P>Chi2
Wolfe Gould	21.96	24	0.582
Brant	-1835	24	1.000
score	23.6	24	0.485
likelihood ratio	22.73	24	0.536
Wald	21.76	24	0.594

Annex Table 8: Pearson pair-wise correlation matrix (STATA 16)

	TLU	**FARINC**	**FS**	**HHA**	**ELHH**	**LS**
Livestock holding	1.0000					
Farm inc	0.3615	1.0000				
Family size	0.1956	0.1285	1.0000			
Age	0.1567	0.0708	0.3114	1.0000		
Education level	-0.0669	-0.0083	-0.2340	-0.5322	1.0000	
Land size	0.2027	0.0805	0.3502	0.3528	-0.1099	1.0000

Annex Table 9: Variance inflation factor

Variable	VIF	1/VIF
CC perception level	2.84	0.352
Age	2.57	0.389
Field day participation	1.89	0.530
Agri.ext.& agri. training	1.74	0.576
Farm Land size	1.63	0.615
Family size	1.62	0.616
Education	1.61	0.622
Livestock holding(TLU)	1.51	0.661
Income from farm	1.40	0.715
Sex	1.25	0.797
Access to credit service	1.18	0.846
Farming system	1.18	0.849
Mean VIF 1.68		

Annex10: Household level and FGD data collection photo.