ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES AND ITS IMPACT ON CROP PRODUCTIVITY AND SMALLHOLDER FARMERS' INCOME; THE CASE OF BIBUGN DISTRICT, AMHARA REGIONAL STATE, ETHIOPIA.

M .Sc. THESIS

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HAWASSA UNIVERSITY, WONDOGENET, ETHIOPIA

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN CLIMATE SMART AGRICULTURAL LANDSCAPE ASSESSMENT

JUNE, 2020

APPROVAL SHEET -I

This is to certify that the thesis entitled "Adoption Of Climate-Smart Agricultural Practices And Its Impact On Crop Productivity And Smallholder Farmers' Income; The Case Of Bibugn District, Amhara Regional State, Ethiopia " submitted in partial fulfillment of the requirement for the degree of Master of Science with specialization in Climate Smart Agricultural Land scape Assessment of the Graduate Program of the school of forestry, Wondo Genet College of Forestry and Natural Resources, and has been carried out by Lakachew Limenih (Id. GPCSALRR/012/11), under our supervision. Therefore we recommend the student has fulfil the requirements and hence hereby can submit the thesis to the department.

Approved by:

Main advisor: Abemayehu Mulluneh (Prof) _[signature]_ June 26, 2020

Name Signature Date

Co- advisor: ______________ ______________ ______________

Name Signature Date

APPROVAL SHEET-II

We, the undersigned, members of the Board of examiners of the final open defense by Lakachew Limenih have read and evaluated the thesis entitled "Adoption Of Climate-Smart Agricultural Practices And Its Impact On Crop Productivity And Smallholder Farmers' Income; The Case Of Bibugn District, Amhara Regional State, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Climate smart agriculture landscape assessment at Wondo Genet College of Forestry and Natural Resources.

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DECLARATION

I, Lakachew Limenih, hereby declare that this MSC thesis is my own original work and has not been presented for any other institution for the award of any academic degree, diploma or certificate in anywhere. Again, all sources of materials used for this thesis have been indicated and duly acknowledged with references.

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Date of submission: ______________________________

ABBREVIATION /ACRONYMS

CA	Conservational Agriculture
CC	Contingency Coefficient
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
CSA	Climate Smart Agriculture
CSAPs	Climate Smart Agricultural Practices
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GHG	Green House Gas
GTP	Growth and Transformation Plan
IPCC	Inter-governmental Panel on Climate Change
KIs	Key Informants
MDGs	Millennium Development Goals
MVM	Multivariate model
NGOs	Non-Governmental Organizations
RLLP	Resilient Landscape and Livelihood Project
SLMP	Sustainable Land Management Program
SSA	Sub Sahara Africa
SWC	Soil and Water Conservation
TLU	Tropical Livestock Unit
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor

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ABSTRACT

About 96% of African agriculture is rain-fed and more than 87% of Ethiopian poor live in rural areas and are dependent on rain-fed agriculture that makes it prone to various weather-related shocks and stresses. Climate smart agricultural (CSA) practices and interventions are being implemented to meet the challenges of changing climate. Despite several CSA practices are practiced by smallholder farmers in different parts of Ethiopia, their role to agricultural productivity and household income in the study area are not well studied. The main objective of this study was to assess adoption of climate smart agriculture practices and its impact on crop productivity and households' income in the district. The study followed a multi-stage sampling procedure to select 147 households (84 adopters and 63 non-adopters) in three rural kebeles. Interviews, group discussions, key informants and field observations tools were employed to collect data. The data analysis was carried out by descriptive, inferential statistics and binary logistic model. Inventory results showed that soil and water conservation practices, crop type diversification, crop rotation with legumes, preparation of organic fertilizer, agroforestry, improved crop varieties, changing planting date were the major CSA practices implemented in the study area. Due to the implementation of CSA practices the mean productivity of main crops have been significantly increased. The increased in productivity for adopters compared to non-adopters for maize, teff, wheat, barley, potato and legume crops was 16.97%, 2.70%, 12.62%, 22.05%, 5.23% and 28.17% respectively. The increased in crop productivity increased -the mean income of CSA adopters to 44988.9ETB as compared to lower income of non-adopters with 33671.4 ETB. This result showed an increase in income by 33.6% because of CSA practices implementation in the area. The result from the binary logit analysis showed that education level, access to extension service, training, demonstration sites, tropical livestock unit (TLU) and access to credit services have a significant and positive influence on adoption of CSA technologies. But dependent ratio has negative and significant effect. It is concluded that CSA practices can play a significant role to enhance household's productivity and income which can reduce impacts of climate change. Finally, it is recommended that Government and non-government organizations should work on farmers to increase awareness and participation to CSA practices.

Keywords: Adoption, Bibugn, Climate smart agriculture, Factor, Sustainable land management

1. INTRODUCTION

1.1. Background

Climate change is emerging as a major threat on agriculture, food security and livelihood of millions of people in many places of the world (IPCC, 2014). These impacts are deepening the problems already being faced by smallholder farmers in developing countries, who are the most vulnerable to climate change (Campbell and Thornton 2014 p. 3), but produce 70% of the world's food needs (FAO, 2013). Over the last few decades, agricultural productivity has been low and stagnant, particularly in smallholder production systems (FAO 2015 p. 1). In some cases productivity has already started declining due to changing rainfall patterns, and increasing frequency of extreme events such as droughts and floods (Lipper et al. 2014 p. 1068). As a result of climate change, yields for key food crops such as maize and wheat have already reduced by an estimated 3.8% and 5.5% respectively, relative to a counter factual without climate trends (Lipper et al. 2014 p. 1068). According to MOALR (2018), Conservative estimates also suggest that climate change will reduce agricultural crop productivity in Ethiopia by 5 -10 percent by 2030.

Several studies indicate that agriculture production could be significantly impacted due to increase in temperature (Aggarwal et al., 2009; Lobell et al., 2012), changes in rainfall patterns (Prasanna, 2014) and variations in frequency and intensity of extreme climatic events such as floods and droughts (Brida and Owiyo, 2013; Singh et al., 2013). Considering the sensitivity of the prevailing farming systems to drought, crop yields are projected to decline by as much as 50% by 2020 across the African continent. Moreover, crop net revenues may fall by up to 90% by 2100 (Jones and Thornton, 2008).

Africa is a drought-prone continent, making farming risky for millions of smallholder farmers who depend on rainfall to water their crops (Nyasimi et. al., 2014). Under current land management practices, population growth predictions, and present production and consumption trends, the food production systems in SSA will meet only 13% of the continent's food needs by 2050 (Juma et al., 2013). Due to the increasing challenges of climate change, rapid population growth, soil fertility decline and postharvest loss, agriculture in SSA faces significant challenges to increasing food production and feeding a growing population without significantly increasing the area under cultivation.

Agriculture is the core sector of the Ethiopian economy and the main source of livelihood for a significant proportion of the population (Di Falco and Veronesi, 2013; Abro et al., 2014; Bachewe et al., 2017). It accounts for up to 80% of the employment, contributes up to 43% to of the gross domestic product (GDP), and makes up to 70% of the country's export revenue (Wondifraw et al., 2014). 96% of African agriculture is rain-fed (World Bank 2008) and in Ethiopia more than 87% of the poor live in rural areas and are dependent on rain-fed agriculture (MOA, 2018) that makes it prone to various weather-related shocks and stresses such as spatial and temporal temperature and rainfall variability and drought (Teklewold et al., 2013; Di Falco and Veronesi, 2013). Climate change may decrease national gross domestic product (GDP) by 8–10% by 2050, but adaptation action in agriculture could cut climate shock-related losses by half (USAID, 2017)

Agriculture production systems require adaptation to these changes in order to ensure the food and livelihood security of farming communities. Adaptation options that sustainably increase productivity, enhance resilience to climatic stresses, and reduce greenhouse gas emissions are known as climate-smart agricultural (CSA) technologies, practices and services (FAO, 2010). Broadly, CSA focuses on developing resilient food production systems that lead to food and income security under progressive climate change and variability (Vermeulen et al., 2012; Lipper et al., 2014). Many agricultural practices and technologies such as minimum tillage, different methods of crop establishment, nutrient and irrigation management and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce Greenhouse Gas (GHG) emissions from agricultural activities (Branca et al., 2011; Jat et al., 2014; Sapkota et al., 2015).

Sustainable agricultural intensification, which entails increasing agricultural productivity on existing farmlands without adverse effects on the environment, is suggested to be the way forward to meet the food demand for the ever increasing population in SSA in the face of climate change (Pretty et al., 2011; Garnett et al., 2013; Frankema, 2014; Godfray and Garnett, 2014). According to (Nyasimi et. al., 2014), a multitude of climate-smart agricultural practices and interventions are being developed in Africa to meet the challenge of a changing climate and especially the prospect of more droughts. For example, empirical results in Tigray region demonstrate enhanced crop productivity, in terms of the impact on productivity, of using compost, compared to commercial fertilizer (Kassie et al. 2009). Previous research in Ethiopia by (Benin 2006; Kassie et al. 2008) has also shown that stone bunds are more productive in drier areas than in wetter areas. Similar results by(Haftu et.al. 2019) Looking at impact of SLM practices on productivity, the value of crop production of SLM users was 77‑100% higher than that of non-continued users on average.

Globally, a large proportion of the country’s land area is undergoing some form of soil erosion or land degradation; hence CSA-related efforts have been focused on restoring degraded lands through soil and water conservation measures, agroforestry, residual management, area closures and dissemination of improved varieties. Such CSA practices and technologies are largely supported by the government and its development partners, through research and development, rural extension and advisory services as well as direct implementation. Many of these practices are implemented within the framework of the integrated watershed management approach through projects such as the Sustainable Land Management Programme (SLMP). According to USAID (2017), Adoption levels of some CSA practices and technologies, such as conservation agriculture and agroforestry, among smallholder farmers remain low. Evidence suggests that the adoption of watershed management practices by farmers varies with respect to a range of demographic, socio-cultural, economic, institutional, and biophysical factors (Teklewold et al., 2013; Kassie et.al., 2015; Asmame & Abegaz, 2017; Mekuriaw et al., 2018).

Therefore this study was carried out to identify and examine types of CSA practices implemented and their impacts to crop productivity and smallholder farmers' income in the study area. The study was also attempt to identify the challenges face for the adoption of CSA interventions by smallholder farmers in the study area.

1.2. Statement of the problem

Ethiopia is one of the most vulnerable country to the adverse effects of climate change due to its geographical location, topography and heavily dependent on rain-fed agriculture, high population growth rate, low economic development level and weak institutions in combination with low adaptive capacity (NAPA, 2007). Farmers of Bibugn district, like smallholder farmers in any other part of Ethiopia, are suffering from climate variability which have become common natural disasters in the country. In order to adapt the effect of climate change to agriculture, government of Ethiopia is doing multiple climate smart agricultural practice to reduce risks associated with climate change. Even different international programs and projects are investing in Ethiopia in order to minimize risks related to climate change.

Different studies of the estimates of the impact of SLM on agricultural output in Ethiopia are mixed, some findings show positive results and others negative. Pender and Gebremedhin (2006) conducted a survey in stone terraces in Tigray region and found significantly higher crop yields on plots with SLM compared with plots that did not practice SLM. Kassie et al. (2007) found positive effects of SLM on value of total crop production in Tigray and Amhara; however, Kassie et.al. (2009) found that plots with an SLM investment in high rainfall areas of Amhara resulted in lower yields compared with plots with no SLM. According to Kassie et al. (2011), minimum tillage has a significant impact in the low-agricultural potential areas, increasing net productivity by ETB 630 ($74) percent in Tigray region and ETB 293 ($34) percent in the low-agricultural potential areas of the Amhara region. Araya et al. (2012) reported that SLM structures be maintained for an average of 5 years to realize a significant increase in crop yield. Given that rural farmers ultimately decide whether to invest in SLM, understanding household level benefits of SLM adoption within a watershed landscape is critical to understanding potential for program sustainability in the long term.

Despite several CSA practices are practiced by smallholder farmers in different parts of the country, Monitoring of such interventions is critical since existing evaluation techniques do not represent local specific situation. In addition to this, information is lacking on the relative contribution of these practices to agricultural productivity and household income in the study area. As site specific issues require site specific knowledge, assessment and documentation of impacts of CSA practice to productivity and households' income and identifying factors influencing the adoption of these practices was very important for the district. Thus, this paper takes a step toward filling this gap by systematically exploring the productivity gains associated with adoption of multiple CSA practices in the study area.

1.3. Objective of the study

1.3.1. General objective

To assess adoption of climate smart agricultural practices and its impact to crop productivity and households' income in sustainable land management project in the study area.

1.3.2. Specific objectives

- To conduct inventory of Climate Smart Agricultural practices implemented by smallholder farmers in the study area
- To explore factors affecting smallholder farmers to adopt climate smart agricultural practice in the study area
- To assess the impacts of climate smart agricultural practices for crop productivity and households income in the study area

1.4. Research question

- What are the main climate smart agricultural practices implemented by smallholder farmers in the study area?
- What is the impacts of CSA practices to crop productivity in the area?
- Does a climate smart agricultural practice contribute to increase/improve household income of smallholder farmers in the study area?
- What are the factors faced to smallholder farmers to adopt multiple climate smart agricultural practices in the study area?

1.5. Significance of the study

Increase in global population, especially in Africa and increased incidents of climate change of which smallholder farmers are vulnerable and have limited coping capabilities to climate change impacts. This resulted in reduced productivity, food shortage, noticeable poverty and nutrition deficiency which remain one of the most fundamental challenges for human welfare and economic growth of the country.

This study was important in that it reveals the impacts of climate smart practices to crop productivity and household income and challenges faced on adopted CSA practices. This is also very crucial to understanding the challenges of smallholder farmers that influences adoption of CSA practices. Furthermore, the results will be used to provide reference for better understanding of the importance of practicing CSA by farmers in the district. Therefore, the outcome of the study is expected to be relevant to many areas of east Gojjam zone and other parts of the county with similar agro-ecology and socio-economic structures. Finally, this finding is useful to the local community and institutions, government at all levels and NGOs who seek to foster wider adoption of CSA by up scaling these practice for sustainable development.

1.6. Scope of the Study

Conceptual Scope:-This study assessed the impacts of climate smart agricultural practices based on the inter-link of adopters and non-adopters to CSA practices in the project area, productivity, income and challenges for adoption of CSA practices. The study was conducted in East Gojjam zone Bibugn district in the selected sample three kebeles.

Temporal or Time Scope-Time series data was employed by using three consecutive 2017/18, 2018/2019, 2019/20 production year and taking the average yield for each adopter and non-adopter households.

Limitation of the study: - This study is limited to assess the impacts of CSA practices on crop productivity and household income in relation to climate change adaptation. Due to time and financial problem the study was relied on some selected kebeles. This may limit the representativeness of the study while aiming to use it at zonal and other higher administrative level.

2. LITERATURE REVIEW

2.1. Definition and concepts

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2012).

Adaptation: Adaptation refers to activities that make people, ecosystems and infrastructure less vulnerable to the impacts of climate change (Shanahan et al., 2013).

Climate Smart Agricultural practices: FAO Defined CSA as agricultural activity that is: sustainably and efficiently increases productivity and incomes (adaptation), reduces or removes Greenhouse gases emissions (mitigation), enhances achievement of national food security and development goals (FAO, 2010).

Adoption: a decision to make full use of on innovation as the best course of action available (Rogers, 2003).

2.2. The concept of climate change

The origin of climate change debate can be traced back to the early1980 as an international environmental and developmental challenge beginning with the publication of the Brundtland Report in 1987. Two years later, the Intergovernmental Panel on climate change (IPCC) was formed to provide reports on climate change. According to IPCC 2012, climate change is change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change is the subject of how weather patterns change over decades or longer. Since the Industrial Revolution (i.e., 1750), humans have contributed to climate change through the emissions of GHGs and aerosols, and through changes in land use, resulting in a rise in global temperatures. Increases in global temperatures may have different impacts, such as an increase in storms, floods, droughts, and sea levels, and the decline of ice sheets, sea ice, and glaciers(CIA, 2015).

In process of global warming earth receives energy through radiation from the sun. GHGs play an important role of trapping heat, maintaining the earth's temperature at a level that can sustain life. This phenomenon is called the greenhouse effect and is natural and necessary to support life on earth. Without the greenhouse effect, the earth would be approximately 33°C cooler than it is today(CIA, 2015). In recent centuries, humans have contributed to an increase in atmospheric GHGs as a result of increased fossil fuel burning and deforestation. The rise in GHGs is the primary cause of global warming over the last century. According to CIA 2015, these analyses all show that Earth's average surface temperature has increased by more than 1.4°F (0.8°C) over the past 100 years, with much of this increase taking place over the past 35 years.

2.3. Climate Change impact on Agriculture

The connection between agriculture and climate change is real and potentially deadly. On one hand, the agricultural value chain, and land use change, including deforestation account for 30% of the total global GHG emissions; while on the other hand, the adverse impacts of climate change are leading to land degradation, and food insecurity (IPCC, 2007). Climate change and variability pose a great threat to food security and income of millions of people around the world. Changes in weather patterns have reduced crop harvest, increased food insecurity and malnutrition as well as poverty (Taneja *et al.*, 2014). Climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and that is in addition to natural climate variability over comparable time periods (UNFCCC, 2007). Over and above, food insecurity and rural poverty remain pressing development concerns in SSA (Majiwa et al., 2018). Based on the study, Countries in the region at high risk of food insecurity and poverty are those in which the livelihood of a high proportion of the population depends on agriculture.

Climate change affects mainly the agricultural sector and agriculture in turn affects climate change through practices. According to Lipper et al. (2014 p. 1068) ,productivity has already started decreasing due to changing rainfall patterns, and increasing frequency of extreme events such as droughts and floods. As a result of climate change, yields for key food crops such as maize and wheat have already reduced by an estimated 3.8% and 5.5% respectively, relative to a counter factual without climate trends (Lipper et al. 2014 p. 1068).

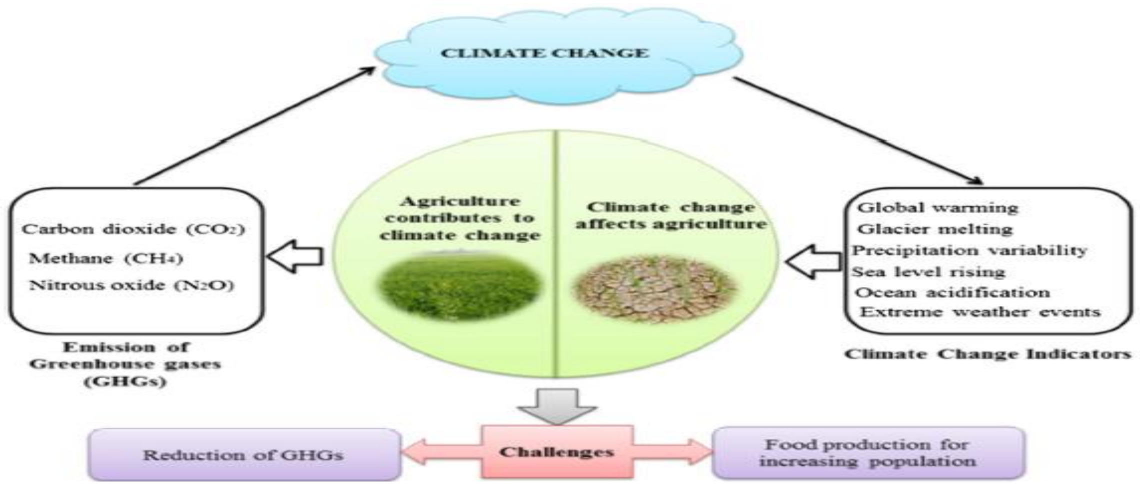

Figure 1. Relation between climate change and agriculture.

(Adapted from (Rinku Singh and G. S. Singh 2017))

Agriculture affects climate change through emission of greenhouses gas (GHG) from different farming practices (Adugna *et al*., 2013). Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change is causing more frequent and intense periods of drought as overall rainfall levels decline. This results in shorter growing seasons for farmers and in prevalence of pests and diseases in areas where they were not previously a threat to crops. Therefore, Livelihood security requires more resilient production systems. Similarly, more productive and resilient agriculture requires management of natural and environmental resources (FAO, 2010). Transiting to such systems could generate significant mitigation benefits (FAO, 2010; World Bank, 2011).

2.4. Impact of climate change on smallholder farmers (income) in Ethiopia

Agriculture is the most important sector in sub-Saharan Africa, but it is predicted to be negatively impacted by climate change. According to FAO (2011), climate change has strong impact on the agricultural sectors and forestry by modifying or degrading productive capacities and by directly and indirectly increasing the risks associated with production. Current climate variability is imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction, and sustainable development efforts (Kristiansen, 2011). Climate change and the associated environmental degradation are emerging as big challenges to Ethiopian agriculture and poverty alleviation efforts (Aragie, 2013). Additionally, rainfall variability has been reported to have significant effect on Ethiopia's economy and food production for the last three decades (Araya & Stroosnijder, 2011). This is due to the fact that the Ethiopian economy is largely dependent on rain fed agriculture, which is heavily sensitive to climate variability and change.

About 70% Ethiopia is arid, semi-arid, or categorized as dry sub-humid; these areas are prone to desertification and drought (NMA, 2007). The production of crops in Ethiopia is dominated by small scale subsistence farmers (CSA, 2013). According to CSA (2013), small-scale farmers on average account for 95% of the total area under crop and for more than 90% of the total agricultural output. It is clear that climate change will bring about substantial welfare losses especially for smallholders whose main source of livelihood derives from agriculture (Paulos Asrat & Belay Simane, 2018). Higher temperatures, reduced rainfall, and increased rainfall variability reduce crop productivity that would be affected food security in low income and agriculture-based economies. According to the report by Deressa (2006), by using Heckman sample selection model both increasing temperature and decreasing precipitation are damaging Ethiopian agriculture.

According to World Bank (2006), 1984-85 drought reduced Ethiopia‘s agricultural production by 21 percent, which led to a 9.7 percent fall in the GDP. Crop and livestock losses over North-Eastern Ethiopia, associated with droughts during 1998-2000, were estimated at US$266 per household, which is greater than the average annual income for 75 percent of the households in this region (Stern, 2007). Impacts are direct results of a climate shocks such as droughts and floods which ultimately decrease yields or even complete losses due to total or partial destruction of crops, livestock, infrastructure and other assets (World Bank, 2007).

2.5. Farming systems and climate-smart agriculture practices in Ethiopia

2.5.1. Farming system in Ethiopia

According to Befekadu and Berhanu (2000), the farming system in Ethiopia can be classified into five major categories – the highland mixed farming system, lowland mixed agriculture, the pastoral system, shifting cultivation and commercial agriculture. According to CSA (2011), In Ethiopia over 95 percent of the annual gross total agricultural output of the country is said to be generated from smallholder farmers with an average farm size ranging from 0.5 to 2 hectares and medium to large-scale commercial farms to gross total agricultural output is only about five percent.

The existence of diverse agro-ecological conditions enables Ethiopia to grow a large variety of crops (CSA, 2011). Even though the country is known to produce various types of crops, food insecurity is a major challenge. The government of Ethiopia has given top priority to the agricultural sector and has taken a number of steps to increase productivity. The strong dependence of the country on agriculture, which is very sensitive to climate variability and change, is a cause for concern. Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO2e in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural land, which accounted for over 50 percent of forestry related emissions, followed by fuel wood consumption at 46 percent of forestry-related emissions (CRGE, 2011).

2.5.2. Concept and practices of CSA practices adopted in Ethiopia

The concept of Climate Smart Agriculture was first presented in FAO meeting at the Hague conference on Food security and climate change in 2010. FAO defined CSA as agricultural activity that: Sustainably and efficiently increases productivity and incomes (adaptation), reduces or removes Greenhouse Gases (mitigation) and enhances achievement of national food security and development goals (FAO, 2010). CSA seeks to increase productivity in an environmentally and socially sustainable way, to strengthen farmers' resilience to climate change, and to reduce agriculture's contribution to climate change by reducing GHG emission and increasing soil carbon sequestration (FAO, 2010; World Bank, 2011).

As part of livelihoods and food security improvement, a multitude of agricultural development activities are conducted in Ethiopia, both traditionally and innovatively. Of the numerous agricultural development activities conducted, mention should be made of those that are considered important in addressing issues related to climate change and are contributing to climate change adaptation and mitigation. Such agricultural practices in Ethiopia include integrated watershed management, integrated soil fertility management, sustainable land management, conservation agriculture, agroforestry, crop residue management, composting, promotion of improved livestock feed and rangeland management (FAO, 2016).

Integrated watershed management: Ethiopia is one of the countries seriously affected by land degradation, and addressing this problem is a major priority for the country. CSA in SLMP2 refers to proven practical techniques such as mulching, intercropping, conservation agriculture, no-till, crop rotation, cover cropping, integrated crop livestock management, agroforestry, improved grazing and improved water management and innovative practices such as use of drought-resistant food crops. Reports indicate that land and crop production and productivity have increased due to an increase in land available for cultivation, increased availability of water for irrigation, improvement in the fertility status of the soil as well as improved agronomic practices (FAO, 2016). It is reported that soil organic matter content sequestration can be achieved by implementing sustainable land management practices that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure and enhance activity and species diversity of soil fauna (Woodfine,2009).

Integrated soil fertility management: As part of integrated soil fertility management, promotion of composting was set as a target in the climate change component of the Growth and Transformation Plan (GTP). According (Jirata et al., 2016), even though activities carried out so far are encouraging, agricultural production in Ethiopia is characterized by low crop productivity owing to a decline in soil fertility. The lack of appropriate and adequate soil fertility management is still a major challenge in smallholder agricultural production.

Manure management and composting: Manure management is important to alleviate climate change as it can be used as organic fertilizer and is also a source of methane (CH4) and Nitrous Oxide (N2O) emissions. When manure is used as organic fertilizer it contributes to the productivity and fertility of the soil by adding organic matter and nutrients. It improves productivity and allows for reductions in use of synthetic fertilizers and the associated direct and indirect GHG emissions (Gerber *et al*., 2010). The increasing geographic concentration of livestock production means that the manure produced by animals often exceeds the absorptive capacity of the local area.

Conservation agriculture: Many areas of Ethiopia are mountainous and the crop fields are rarely flat often they are located in a hill side or in a valley side. This creates extra demand for soil and water conservation to prevent the soil and rainwater from being washed away. The structures for soil and water conservation, which include terraces, bunds, contour cultivation, grass strips, check dams. The goal of all these structures is to reduce run-off and soil erosion, which can help to increase yields, especially on steeply sloped land (Obalum *et al*., 2011). According to FAO (2016), In Ethiopia, soil conservation practices such as reduced tillage have long been undertaken by farmers.

The general pattern emerging from these data is that yields increase both in the short and long term as a result of conservation agriculture. Similar researches in Latin America, Africa and Asia conclude that conservation agriculture yields are between 20 to 120 percent higher than those in conventional agriculture (Kassam et al., 2009). There are several mechanisms by which conservation agriculture can improve yields. Mulching and residue management can increase soil fertility and the availability of nutrients to plants. In terms of adoption of conservation agriculture, information from various sources indicates that in areas where conservation agriculture has been adequately demonstrated, for example in some parts of Amhara, Oromia and Tigray, adoption has been reported to be significant.

Agroforestry: Agroforestry is an old agricultural activity traditionally practiced in many parts of Ethiopia. The agroforestry practices intended to address issues of soil erosion and diversification of farm produce as well as agricultural yield, resilience to climate variability (for example through provision of shade during hot spells) and creation of favorable microclimates for certain crops. The practice involves the integration of trees and shrubs into farmland either through planting or natural regeneration. Integrating perennial trees or shrubs in agricultural lands used both for crop production and grazing in Ethiopia has been documented to improve soil cover and ensure green cover during the off-season (Kitalyi et al., 2011).

Crop rotation and intercropping: In Ethiopia the promotion of crop rotation is conducted in many parts of the country as a regular extension programme. Crop rotation effectively delivers on both climate change adaptation and mitigation. Practicing crop rotation and intercropping has many advantages, which include reduced risk of pest and weed infestations; better distribution of water and nutrients through the soil profile; exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species. Better nutrient management through crop rotation can decrease the use of nitrogen fertilizer and related greenhouse gas (GHG) emissions associated with the production, transportation and use of chemical fertilizers (PANW, 2012).

Crop diversification:- Unpredictable and unusual weather exposes farm households in developing countries to pervasive production risks with significant impacts on food production, income and consumption (Dercon, 2004; Gao and Mills, 2018). Crop choice or diversification decisions will be determined by households' willingness to bear risk, the availability of consumption smoothing measures, and households' preferences (Arslan et al., 2018; Asfaw et al., 2018). When environmental risks increase, crop diversification can be a natural insurance (as opposed to financial insurance) against downside risk or crop failure and increases production and food consumption (Baumgärtner and Quaas, 2010).

Table 1: Some common CSA practices in Ethiopia

CSA practices	Components	Why it is climate smart
Conservation agriculture	• Reduced tillage • Crop residue management –mulching, intercropping • Crop rotation/intercropping	• Carbon sequestration • Reduce existing emissions • Resilience to dry and hot spells
Integrated soil fertility management	• Compost, manure management, green manuring • Efficient fertilizer application techniques (time, method, amount)	• Reduced emission of nitrous oxide and CH4 • Improved soil productivity
Small-scale irrigation	• Year-round cropping • Efficient water utilization	• Creating carbon sink • Improved yields • Improved food security
Agroforestry	• Tree-based conservation agriculture • Practiced both traditionally and as improved practice • Farmer-managed natural regeneration	• Trees store large quantities of CO2 • Can support resilience and improved productivity
Crop diversification	• Popularization of new crops and crop varieties • Pest resistance, high yielding, tolerant to drought, short season	• Resilience to weather variability • Alternative livelihoods and improved incomes

Source: (Adapted from FAO, 2016)

In Ethiopia various projects and programmes are implemented in different agro-ecological zones of the country. These programs and projects includes Climate-Smart Initiative for

PSNP and HABP, Farm Africa and SOS Sahel, PSNP-PW, Reducing Emissions from Deforestation and Forest Degradation (REDD+), Enhancing income of smallholder farmers through integrated soil fertility management, Humbo Assisted Natural Regeneration Project (Afforestation and Reforestation), Agricultural Growth Project (AGP), Sustainable Land Management (SLM) Programme etc.

2.6. Role of CSA practices for enhanced income of rural households

Climate-smart farming practices can help farmers be more resilient to drought and other changing weather patterns. Climate-smart agriculture has potential to help farmers adapt to and mitigate climate change. Many agricultural practices contribute to both adaptation and mitigation goals simultaneously. Years of trials on farmers' fields have shown that conservation agriculture produces 11-70% higher and more stable yields compared to the traditional conventional ridge tillage system (Nyasimi et. al., 2014). Opportunities to safe production space include the adoption of climate-smart agricultural practices that would reduce food loss (e.g. storage innovations), mitigate climate change (e.g. conservation agriculture), and climate change adaptation and yield improvements (e.g. crop diversification, conservation agriculture); (Beddington et al., 2012; Neufeldt et al., 2013). CA is one of the numerous agricultural development activities started in 1998 in Ethiopia to improve crop productivity while addressing issues related to climate change, poor soil fertility, and preserving the underlying natural resource base (Marenya et al., 2015; Jirata et al., 2016). CA would affect household poverty through its potential role in reducing production costs (Tambo and Mockshell, 2018) and mitigating production risks (Teklewold et al., 2013; Kassie et al., 2015) that would enhance farm income. Another CSA practice is crop diversification, which enhances crop productivity at the household level by increasing yield (Di Falco et al., 2010; Chavas and Di Falco, 2012). When environmental risks increase, crop diversification can be a natural insurance against downside risk or crop failure and increases production and food consumption (Baumgärtner and Quaas, 2010). In rural areas crop diversification can be an effective risk coping strategy (Loison, 2015).

2.7. Factors influencing adoption of CSA strategies

Adapting to weather and climate is a characteristic of all human societies, but climate change is presenting new and increasing challenges. Smallholder farmers in Africa are using their knowledge, experience and resources to manage climate risks on their own account but these actions are not easily distinguished from a range of other social, demographic and economic factors influencing livelihood decisions and development trajectories (Adger et, al., 2003). In spite of the potential of CSA to improve resilience and to enhance agricultural production and rural livelihoods, systematic response to climate change through adoption of CSA practices and technologies is still very limited in Africa for a multitude of reasons(Barnard et al., 2015). The first relates to the physical means or the hardware barriers and include physical inputs such as land, human resources, equipment, infrastructure and finances. The second, referred to as the non-physical or software barriers, relates to the institutional, cultural, policy and regulatory environments; information, knowledge and skills; technologies and innovations; and governance among others.

Socio-economic factors that influence adoption of adaptation strategies include household characteristics and farm characteristics. The household characteristics that can potentially influence adoption decisions include age, education level, gender of the head of the household, household size, years of farming experience, attitude towards risk and wealth.

The age of a farmer may positively or negatively influence the decision to adopt new technologies (Gbegeh & Akubuilo, 2013). Older farmers have more experience in farming and are better able to assess the characteristics of modern technology than younger farmers, and hence a higher likelihood of adopting the practice. On the other hand, older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies (Adesina & Forson, 1995).

Education level is often assumed to increase the likelihood of embracing new technologies as it enhances the famer’s ability to recognize the effects of climate change (Nkonya et al., 2008). It enables households to access and conceptualize information relevant to making innovative decisions (Adesina & Forson 1995; Owuor & Bebe, 2012). However, higher educational attainment can present a constraint to adoption because it offers alternative livelihood strategies, which may compete with agricultural production.

The effect of gender of household head on adoption decisions is location-specific culture driven (Gbetibouo, 2009). In many parts of Africa, women are often deprived of property rights due to social barriers (Gbegeh & Akubuilo, 2012). However, female-headed households are more likely to take up climate change adaptation measures (Nhemachena & Hassan, 2007; Gbetibouo, 2009). The possible reason for this observation is that in most rural smallholder farming communities in Africa, more women than men live in rural areas where much of the agricultural work is done.

Farmer’s wealth has a significant influence on ability of smallholder farmers to adopt certain technological practices (Nkonya et al., 2008; Gbetibouo, 2009). Households with higher income and greater assets like land and other valuable movable assets are less risk averse than lower income households, and therefore are better placed to adopt new farming technologies (Shiferaw & Holden, 1998).

The influence of household size on the decision to adopt new farming techniques in response to climate change is uncertain. Household size as a proxy to labor availability may influence the adoption of a new technology positively as its availability reduces the labor constraints (Marenya and Barrett, 2007; Teklewold et al., 2013). Given that the bulk of labor for most farm operations in Sub-Saharan Africa is provided by the family rather than hired, lack of adequate family labor accompanied by inability to hire labor can seriously constrain adoption practices (Nkonya et al., 2008).

On the other hand, institutional factors could also influence adoption of new technologies and they include; access to credit, access to information, off-farm employment, land ownership, group membership and government policies (Adesina & Forson, 1995; Gbetibouo, 2009). Adoption of new farming strategies require funds and lack of borrowing capacity may limit ability of farmers to embrace adaptation measures that require heavy investment for instance in strategies such as irrigation, terracing, tree planting soil testing and fertilizer use (Gbetibouo, 2009).

Access to information may influence farmers" decision to adopt new technologies as they were made aware about its existence. Similarly, farmer to farmer extension and information sharing about future climate change may enable them to adjust their farming practices in response to climate change (Gbetibouo, 2009). Government extension service officers target farmer groups for demonstration of new technology.

Land ownership has an implication on the property rights and long term investment in climate change adaptation strategies. For instance, tenure security can contribute to adoption of technologies linked to land such as irrigation equipment or soil conservation practices. Farmers lack economic incentives to invest their time or money if they cannot capture the full benefits of their investments (Gbetibouo, 2009).

2.8. Conceptual framework

The conceptual frame work acts like a map that gives coherence to empirical inquiry (Shields and Tajalli, 2006). Agricultural technology is generally based on the expected benefit derived from technology practice, where farmers are assumed to maximize their benefit from the practices of agriculture. Figure 2 shows the conceptual framework which depicts links between climate change shocks (bad incidents), adaptation strategies of CSA practices, and challenges to adoption, climate change resilience and improved food security. CSA is indicated as a responsive measure to climate change impacts which includes both proactive and planned adaptation measures. Well instituted CSA improves resilience, crop and livestock yields. Improvement in yields leads to higher incomes. Higher incomes lead to improved food security at four levels availability, accessibility, utilization and stability). CSA practice apart from improving resilience of agricultural systems can also reduce GHG emission climate change impacts. But institutional and socio-economic factors are intervening in the framework to influence the adoption of the CSA practices.

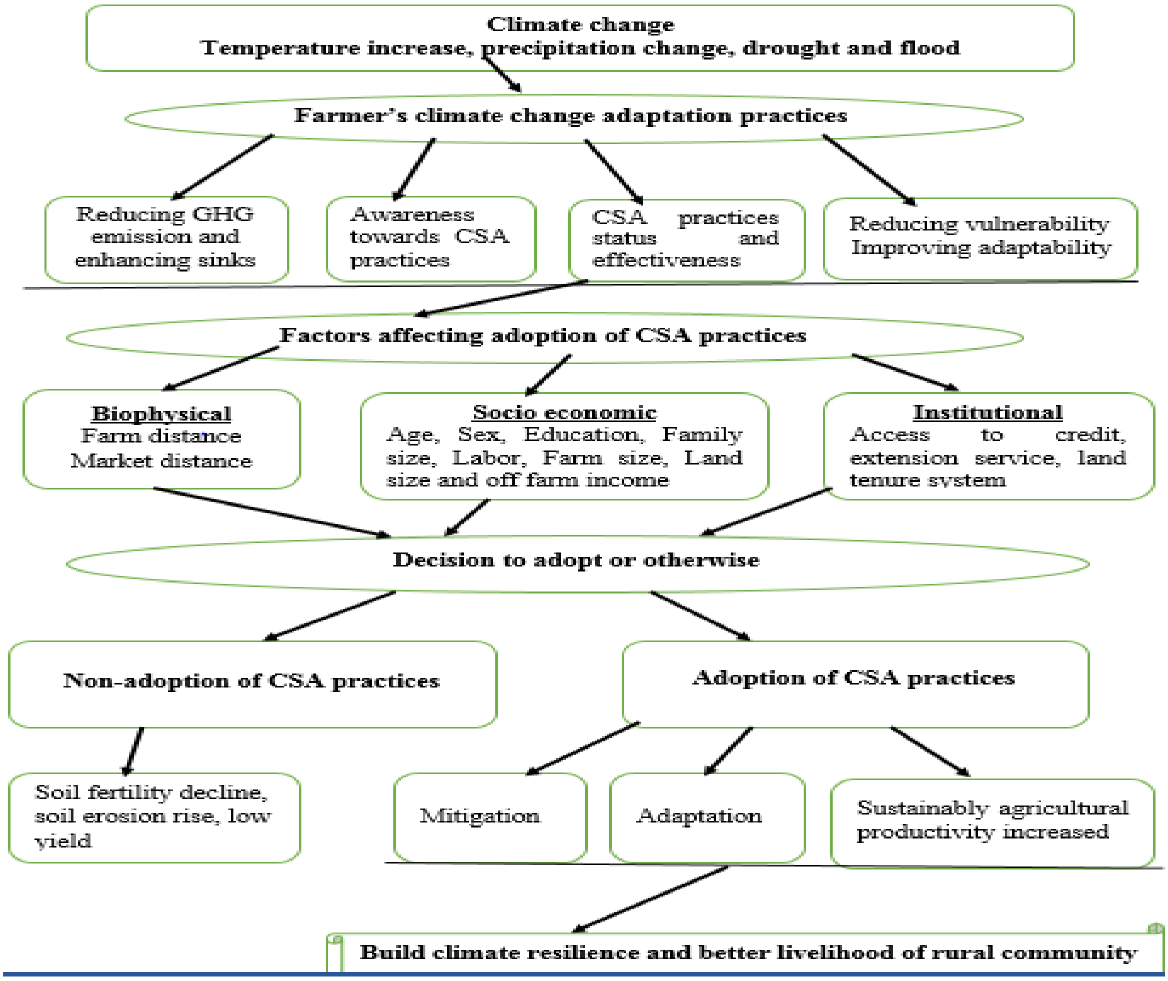

Figure 2. Conceptual frame work

(Source: adapted from Tewodros Beyene, (2018))

3. METHODOLOGY

3.1. Description of the Study Area

Bibugn is one of the districts in Amhara Reginal state of Ethiopia. It is one of the 18 districts' in East Gojjam Zone and is bordered on the south by Sinan district, on the west by Degadamot district, on the northwest by Goncha siso enesie district, and on the east by Hulet Eju Enese districts. It is found 383 km away from Addis Ababa, 184 km from Bahir Dar town and 81 km away to the capital city of East Gojjam zone; Debre Markos town. The district has 15 rural kebeles'. Among them 6 kebeles are supported by sustainable land management project (SLMP) where Climate smart agricultural practices are one of the components. The total area of the district is 39,129 ha. According to BWAO (2019), the land use data shows that Cultivation land 55.8 % (21,833.9 ha), grazing land 18.4 % (7,199.7 ha), Forest land 15.5 % (6,065 ha) and the remaining 10.3 % (4,030.4 ha) is degraded land and construction / settlement.

3.1.1. Population

According to CSA (2017), the population of Bibugn district rural farmer was 87,529. Out of this 42,568 (48.64%) were males and 44,961(51.36%) were females. From this total population, 14563 are farming households engaged in rural farming. The rural population is 81,587 of whom 39,951are males and 41,637 are females. Bibugn district is one of the most densely populated administrative district in East Gojjam Zone, averaging 224 persons per km^2. The largest ethnic group reported in Bibugn was the Amhara (99.9%). All the residents of the study area are native speakers of Amharic language. The majority (99.56%) of the inhabitants practiced Ethiopian Orthodox Christianity as their religion.

3.1.2. Geographical Location

The geographical location of the study area is located within Latitude 11° 00' 0.00" N and Longitude 37° 34' 59.99" E.

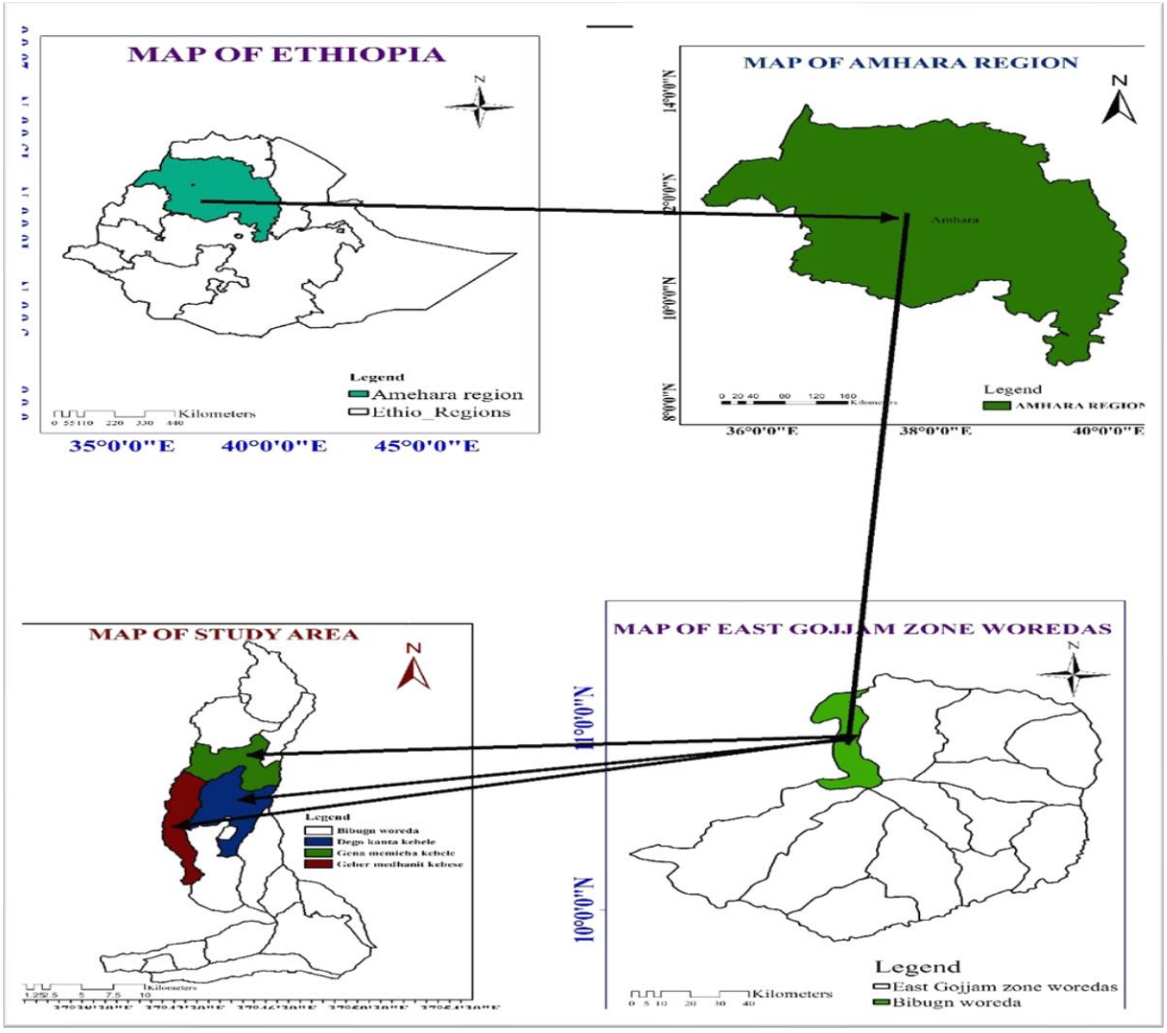

*Figure 3. L*ocation map of the study area

3.1.3. Topography, climate and soil

According to Bibugn district Agriculture Office annual report (2019), the district has a mild climate and its altitude range from 1820-4088 meters above sea level. Its average daily temperature is moderate. The amount of rain fall of Bibugn district varies from 1200-1800 mm and the average is 1500 mm annually. The rainfall pattern of the area is similar to other parts of Ethiopia with the long rainy season starting in June and extending up to September, while the short rainy season begins in March and extends to April/May. The climatic condition of the district is divided into temperate (Dega) 35.53%, subtropical

(Woina Dega) 48.06%, and arid (Kola) 14.46% and 1.955% frost agro-climatic zones (BWAOP, 2019).

3.1.4. Means of livelihood and sources of income

The main economic activities of the local communities are mixed farming involving the cultivation of crops and animal rearing. The main crops includes maize, teff, wheat, barley, potato, bean, and pea in combination with cattle, sheep, goat and small traditional poultry rearing. To increase household income and food security, smallholder farmers' grow different fruits and vegetables around their home as an agro forestry practice. These products serve for household consumption, for cash income or for both.

3.2. Selection of specific study site

Ethiopia which is dependent on rain-fed agriculture together with low level of socioeconomic development is highly affected and vulnerable to climate change. Thus, understanding smallholder farmers' responses to climatic variability and changes are crucial in designing appropriate adaptation strategies. The government of Ethiopia has given top priority to the agricultural sector and has taken a number of steps to increase productivity. Bibugn district is also one of the district which is highly degraded, low soil fertility, sloping and plateau which is highly prone to erosion and land degradation and thus climate change is aggravating those problems.

In the study area, SLMP takes over the initiative to minimize the impacts of climate change to smallholder farmers through implementation of climate smart agricultural practice. It starts in the district in 2014 and the project is now implementing the practices in 6 pilot kebeles from a total of 15 rural kebeles. For this case, the area was selected for investigation to make an assessment of the role of these adaptation strategies to income of smallholder farmers. To select the representative samples, first consultation was made with the district agricultural office management bodies and development agents. According to the data gained, SLMP kebeles were homogenies in farming system, economic status, and agro ecology

3.3. Overview of the Resilient Landscape and Livelihood Project (RLLP)

According to FAO (2016), the first phase of the SLMP (SLM I) was launched in 2008. It has successfully introduced a number of sustainable land management practices and rehabilitated thousands of hectares of degraded land using physical and biological measures and watersheds. The second phase (SLMP II) for the period 2013-2018 builds on the results of SLMP I. SLM II introduced measures to address climate change or variability related risks and to maximize greenhouse gas (GHG) emission reductions so as to meet targets the GTP and the Climate Resilient Green Economy (CRGE, 2011) goals, while reducing land degradation and improving land productivity of smallholder farmers. According to MOA (2018) assessment report, the RLLP was built on the results of SLMP I & II, also introduce measures to address climate change/variability related risks and minimize Green House Gas (GHG) emission reductions to meet the Growth and Transformation Plan (GTP) and the Climate Resilient Green Economy (CRGE) goals of the country.

The project has four components, of which component 1 on integrated watershed and landscape management is crucial as far as CSA is concerned. The main aim was enhancing the livelihood resilience of beneficiary households through Climate-Smart Agriculture (CSA) interventions in all eligible micro-watersheds assisted by the project. The improved adaptation of restored watersheds to variable rainfall patterns and adverse climatic events, combined with reduced degradation-related risks, will provide suitable conditions for beneficiaries to adopt improved, climate-smart farming practices and diversify and/or intensify their current production systems.

3.4. Research design and methodology

3.4.1. Sampling technique and sample size determination

A multi- stage sampling technique was employed to select sample households. In the first stage, the study area, Bibugn district, was purposively selected because of the SLM project in the district and accessibility of data's. In the second stage, from six SLMP kebeles, three kebeles were selected by simple random sampling method; Gena Memecha, Debre Medihanit and Digo Kanta kebles. In the third stage, within the selected kebeles, households who are in the project kebeles were stratified into CSA adopters and non-adopters.

Simple random sampling method was employed given that the sample size of the study to be as representative as possible in accordance with the time and budget allocated. In addition the rationale for deciding this sample method was also based on the assumption that homogeneity of population, cost of the survey, time and no important factor between households that affects the data. For every selected sample size of adopter and non-adopters proportional sample sizes were selected.

Here adopters were households with in the project area and continuous users of CSA practice intensively with close follow up and continuous training with development agents in general whereas non- adopters were farmers with CSA practices in their farm but not efficiently utilizing the practices. The sample size was calculated by using the following formula developed by Cochran (1977) at 95% confidence level as;

$$\text{n} = \frac{N * z^2 * p * q}{e^2(N-1) + z^2 * p * q} = \frac{2422 * 1.96^2 * 0.5 * 0.5}{0.08^2(2422-1) + x1.96^2 * 0.5 * 0.5} = 147 \ldots\ldots\ldots..(1)$$

Therefore, the total sample size was 147. Where *n* is sample size, N is total population size of household heads in the three kebeles and e is levels of precision (i.e. 0.08), p=0.5 the maximum level of variability taken when previous population variability is unknown; q=1-0.5 and Z is confidence level=1.96.

The required sample households of each stratum which is adopter and non-adopter of CSA will be determined by the following formula.

$$n1 = \frac{N1(n)}{\Sigma N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Finally, from a total of 147 sample households, 84 CSA adopters and 63 non-adopters was selected by simple random sampling using probability proportional to size sampling technique.

Table 2. Number of households for two strata from each kebeles.

Selected Kebele	Total HH	CSA adopter		Non-adopter		Total Sample taken
		Total HH	Sample HH	Total HH	Sample HH	
Debre Medihanit	793	473	(473*147)/2422=29	320	(320*147)/2422=19	48
Digo Kaneta	875	454	(454*147)/2422=28	421	(421*147)/2422=26	54
Gena Memecha	754	449	(449*147)/2422=27	305	(305*147)/2422=18	45
total	2422	1376	(1376*147)/2422= 84	1046	1046*147/2422= 63	147

Source: Owen computation (2020)

3.5. Data collection

Both quantitative and qualitative data were collected from primary and secondary sources. Primary data was collected from KIs, FGDs and household survey. Secondary data was obtained from relevant published and unpublished data sources. FGDs and Key informants interview was mainly aim at collection of qualitative information on: - the effect of CSA practices on household income, adaptation capacity to climate changes, and the constraints that influence the adoption of climate smart agricultural practices. Quantitative data's were collected for the effects of CSA practices on productivity and household income in the area.

Accordingly, the data was collected based on some identified indicators. Indicators for inventorying CSA practices includes:-type of CSA practices implemented in the area, years started, current status, how it differs from conventional agriculture, farmers opinion about the practice, advantages of using the practice etc.

Indicators for role of CSA practices includes increased productivity, increased income of households, adaptability to climate change and variability, environmental sustainability, etc.

Indicators for the challenges for CSA practice adoption includes age, family size, land tenure system, education, family size, information and awareness, land size, gender etc.

3.6. Data sources

3.6.1. Primary data sources

Husehold survey: Questionnaire were used to interview the household. The questionnaires were first prepared in English and translated into local language known as "Amharic". The questionnaire were designed to collect data on household characteristics, resource endowment, climate smart agricultural practices implemented, sources of income, types of crops grown and their production. The questionnaire was pre-tested and adjusted as per the response. Finlay, enumerators who have a certificate in agriculture and natural resource areas were recruited from the three kebele and trained for one day on how to collect data and contents of the questionnaire. The enumerators were monitored by the researcher.

Focused group discussion: In a focus group discussion, a group of people having similar concerns and experience regarding the subject were encouraged to participate. Focus group discussions (FGD) were conducted with development agents and adopter and non-adopter farmers to gather qualitative data's. The FGD considered 6-12 individuals per kebele (Elder, 2009). Therefore, one FGD in each sample kebeles that make up a total of three FGDs which have 21 households were participated in the discussion. The discussion was facilitated by the researcher together with the enumerators based on the designed check list.

Key informant interview: Key informants (KIs) are those people who are knowledgeable about the area and the major issues of the study (Elder, 2009). For this study, KIs are peoples who have certainly lived in the area long enough to clarify the issue of interest and are knowledgeable and understanding about the existing trend of climate change, the current status of CSA practices and their role to climate change adaptation in the area. In general, 12 KIs were selected in order to obtain information for a sort of data triangulation. The key informants was done individually interviewed on the overall information that has risen as criteria.

Observation: In order to handle the most relevant information, transect walks with the researchers, Development agents (Das), model farmers and kebele leaders across the area was conducted. During the transect walks, effects of climate change on agriculture, types of CSA practices implemented in the project areas and outside the project, results achieved because of these practices, and smallholder farmers attitude to these practices were assessed.

3.6.2. Secondary data source

Secondary data collection was collected from published documents like literature (previous reports-published and unpublished) and books.

3.7. Methods of data analysis

The collected data was analyzed by using SPSS software (version 25) for household survey data analysis. Descriptive, inferential statistics and econometric model was applied.

Descriptive statistics such as frequency distribution, mean, standard deviation and percentage was used to analyze the quantitative data. The descriptive statistical tools can strengthen the findings of econometric model. Mostly cross tabulation analysis was employed for categorical variables since frequencies do not give information about the relationship between categorical variables and T-test tool was employed for continuous data analysis. These descriptive analyses method was used to identify types of climate smart agricultural practices commonly used in the study area.

Inferential statistics such as regression analysis using binary logit model was employed to identify determinant factors that influence the adoption of CSA practices by rural famers using computer software programme called statistical package for social sciences (SPSS version 25.0). Chi-square(X^2) was used to identify the association between categorical variables and independent t-test was used to compare the mean difference between adopters and non-adopters across the continuous variables, while taking the research objective take in to consideration. Data that obtained from KIs and FGDs were analyzed in qualitative way.

Econometric model specification

Econometric model was used to identify factors affecting farmers' decision to continuous use of climate smart agricultural practices to response climate change and variability. Models normally used for examining relationships between qualitative dependent variables and mixed independent variables.

Binary logit model

The determinant factors for the continued use of CSA practices were estimated using a binary logit regression. According to Gujarati (2004) logistic regression model use when the dependent variable is dichotomy and the independent variables are of any type. It also shows that binary logistic regression is preferred for the dependent variable which have binary outcome that is easy to interpret and provides odds ratios. Following Garson (2008), which applies maximum likelihood estimation after transforming the dependent into a logit variable, the classification of households into a binary model, continued user and non-user, was done based on households' experiences in CSA practices. The dependent variable, which is the natural log of the odds (logit), is binary as shown in Eq. 1.

Binary logistic regression model was applied to analysis parameters of binary logistic regression model for factors influencing the adaptation of climate smart agricultural practices implemented by SLMP. Households who are in the project area and whose farm plot/s is/are well conserved and regularly maintained with the introduced CSA modern conservation measures were considered as continued users (adopters) in this analysis. On the other side, households who are not in the project area and are unwilling to use continuously the introduced conservation structure (previously introduced by a project assistant or mass mobilization) were labeled as non-continued users (non-adopters). The binary choices in this case are households that adopted and are also continuously maintaining the introduced CSA practices (Y = 1) and households that had removed/or unwilling to maintain conservation measures built in the past (Y = 0). This dependent variable may affected by different socio economic and farm specific characteristic. The functional form of logit model is specified as follows:

$$P_i = E(y = \frac{1}{xi}) = \frac{1}{1 + e^{-(Bo + BiXi)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For ease of exposition it can write Equation (1) as $P_i = \frac{1}{1 + e^{-zi}}$ …………… (2)

The probability that a given household is CSA adopter is expressed by (2) while the probability for non-adopter

$1-P_i = P_i = \frac{1}{1+e^{zi}}$…………………. (3)

Therefore it can be written as

$\frac{Pi}{1-Pi} = \frac{1+e^{zi}}{1+e^{-zi}} = e^{zi}$ ……………… (4)

Now ($\frac{Pi}{1-Pi}$) is simply the odds ratio in favor of participation to climate agricultural practice implemented by SLMP, the ratio of the probability that will be non-adopter. Finally taking the natural log of equation (4) it obtains:

$L_i = \ln\left[\frac{Pi}{1-Pi}\right] = z = B_0+B_1X_1 + B_2X_2 + B_kX_k$ where X_1, X2+…. + X_k………… (5)

Where Pi is the probability being CSAP implemented by adopters, ranges from 0 to 1.

Zi= is a function of n- explanatory variables(x) which also expressed

$Z_i = B_0+B_1X_1 + B_2X_2 + BkXk$, B_0 = intercept, B_1, B_2….. B_k slopes of the equation in the model.

L_i = is log of the odds ratio, which is not only linear in x_i but also linear in parameters. X_i = is vector of relevant household characteristics. If the disturbance term (u_i) is introduced, the logit model becomes:

$Z = B_0+B_1X_1 + B_2X_2 + B_kX_k$ where X_1, X2+…. + X_k + U_i. (6)

Where B0 is the constant and Y is continued use of CSA technologies = PrY (1 = a household chooses to use CSA practice, 0 = otherwise).

B1…Bn is the estimated coefficients, and U_i is an error term

X1…Xn = vectors of explanatory/independent variables included in the model

Multicollinearity test was applied before estimating the model between explanatory variables to meet the assumption of Classical Normal Linear Regression Model (CNLM).

Due to this, variance inflation factor for continuous and contingency coefficient test for dummy variables association was tested.

$$VIF = \frac{1}{TOL} = \frac{1}{1-R_i^2} \text{ -- (1)}$$

Where VIF = variance inflation factor, TOL= tolerance which is the inverse of VIF, R_i^2 is coefficient of determination in the regression of one explanatory (x_i) on other explanatory variable (x_j). As a rule of thumb, if the VIF of a variable exceeds 10, which will happen if R_i^2 exceeds 0.90, or if tolerance close to zero that the variable is said be highly collinear (Gujirati, 2004). To avoid a serious problem of multicollinearity, it is quit essential to omit the variables with VIF exceeds 10 in case of continuous variables.

$$CC = \sqrt{\frac{x^2}{N+x^2}} \text{ -- (2)}$$

Where CC = contingency coefficient, X^2 = chi-square, N = total sample size. If contingency coefficient test value exceeds 0.8 for those dummy variables, there is a multicollinearity problem (Gujirati, 2004).

Definition of the Model variables for Binary Logit Model

Once the analytical procedures and their requirements are known, it necessary to identify the potential variables and describe the measurements (Kamara et al., 2002). Accordingly, the variables expected to have influence on continues use of CSA practices are explained below.

Dependent variables

Household participation on CSA practices (1 for adopter and 0 for non-adopter) will be investigated as dependent variable. Based on the review of the literatures and practical experiences, explanatory variables which have logical and justifiable rational in determining household participation to CSA were identified.

Gender of the household head: This is a dummy variable with 1 for male and 0 otherwise. In Ethiopia, household head is the decision maker for farm activities. Male household heads are expected to decide for participation in new technologies and have higher income compared to female household heads because of better labor inputs used in male-headed households (Evans et al., 2018). Therefore, this variable was hypothesized as, if the household head is female there would be low probability of participating in CSA practice and less area of land to be covered by CSA technologies. Hence it is expected to be positive or negative.

Farmer Age: This is a continuous variable and represents the experience of the household in the farming activities. The expected sign of the coefficient on age is indeterminate. It is believed that with age, farmers accumulate more capital and are therefore more able to take on adopting a new technology (Nkamleu *et al. 2*005). It may also be that younger household heads are more flexible and therefore more likely to adopt a new technology.

Education level of household: It is a continuous variable measured in formal schooling years completed by the household head. Available human capital, primarily farmer education level has been included in most of the existing empirical studies on technology adoption. Nelson and Phelps (1966) assert, "Education enhances one's ability to receive, decode, and understand information". In almost all empirical studies the authors found education was positively related to agricultural technology adoption. This is consistent with existing literature which finds that education creates a favorable mental attitude for the acceptance of new practices especially of information-sensitive and management-sensitive practices (Caswell *et al*. 2001). Hence, education has positive contribution to adoption of CSA practices.

Family size: It is a continuous variable measured in the number of peoples living in the household. A household who has more number of family members could share the work load to them and contribute a lot to the income of the specific household. Evidences show that the farmers with higher family size were found participating in different agricultural practice more than those with lower family size (Tewodros *et al*., 2013;Woldegebrial et al., 2015). Hence, it was expected to influence the adoption of CSA practices of the household positively.

Cultivated land Size: We expect that the sign of the coefficient on plot size will be positive, implying that farmers with larger farmers are more likely to adopt an innovative technology. It has been argued that farmers with larger plots can mitigate the risk of taking on a new technology as they can afford to devote only part of their plot to a new technology (Uaiene *et al*. 2009) Several studies have examined the influence of farm size on the adoption decision (Adesine and Chianu, 2002). Parvan (2011) stated "farmers with larger farms are more likely to adopt an agricultural technology, and also more likely to remain adopters".

Total Livestock Holdings /TLU/: This refers to total number of livestock measured in tropical livestock unit (TLU). Livestock is important source of income, food and draught power for crop cultivation in Ethiopian agriculture. Households with more number of livestock have a chance to obtain more direct food or income to purchase foods commodities, particularly during food crisis. Therefore, higher livestock size would significantly increase the household participation to different agricultural activities that enables to increase status of income (Dillon, 2011; Chazovachii,2012; Fanadzo, 2012; and Leta,2018).

Access to Credit: Smallholders in Africa are one of the most risk averse populations as the well-being and health of their entire household relies heavily, if not solely on the success of their plot's productivity. Constrained access to credit is one of the most often cited reasons that technology does not diffuse among the targeted population (Feder *et al. 1*985). The expected sign of the coefficient on credit is positive. Access to credit, whether from formal or informal markets, can be a means to mitigate the financial risks associated with initial adoption costs.

Availability of Agricultural Information: Refers to the frequency of getting information and contact those respondents with development agent. It is the continuous variable. Reliable agricultural information can influence the decision to adopt by shaping attitudes towards and awareness of available technologies (Sunding and Zilberman 2001). Awareness is essentially the first step to adopting an innovative technology, especially one that is not yet widely known. It is important that reliable, technology-specific information be available to farmers in order to promote successful adoption. The expected sign on the coefficient of access to agricultural information is positive. Sources of reliable information such radio or contact with extension agents is expected to stimulate adoption (Polson and Spencer 1991).

Table 3. Description of independent variables

Dependent V.	**Variable type**	**Variable measurement**	**Expected effect(sign)**
Adoption status	Dummy	1 if adopted, 0 otherwise	
Independent variables			
Age of household head	Continuous	Year	-
Sex of household head	Dummy	0 if Female, 1 otherwise	+/-
Level of education	Dummy	0=illiterate, 1=grade 1-4, 2=grade 5-8, 3= grade 9-12	+

Family size of the household	Continuous	Number	+
Off-Farm income of the household	Continuous	Birr	+
Farm size	Continuous	Hectare	+
Livestock ownership	Continuous	Tropical Livestock Unit (TLU)	+
Credit access	Dummy	1 if there is access, 0 otherwise	+
Frequency of Extension contact	Dummy	1=once a week, 2= once in two weeks, 3=once in a month	+
Training given for HHs	Dummy	1 if there is access, 0 otherwise	+
Demonstration sites by HHs	Dummy	1 if there is access, 0 otherwise	+

4. RESULTS AND DISCUSSION

4.1. Characteristics of sample households

Demographic characteristics of households

Differences between CSA adopter and non-adopters households regarding their socio-economic, institutional and demographic characteristics is presented in Table 4. From the total 147 sample population the proportion of male and female households' were 134(91.2%) and 13(8.8%), whereas the proportion of the male headed households for adopters and non-adopters were about 54.4% and 36.70% respectively. Male households are more likely adopters of CSA practices compared to non-adopters.

Education was believed to be an important feature that determines the readiness of the household head to accept new ideas and innovations regarding climate change adaptation strategies and efficient use of resources. The empirical result indicated in table (4) shown that about one third of the total sample population had no the chance of attending school but three-fourth have got attend from primary to higher education level. From the adopter sample households about one-tenth had no chance of attending school but more than half of the non-adopters had no the chance of attending school. The chi-square test (x^2 =40.143, p=0.000) indicates that, there was a significance difference and an association in education level between adopters and non-adopters of CSA practices. Adopter households were educated than non-adopters, Which indicates educational background of households increase the likelihood of adoption of CSA practices better compared to illiterates at 95% level of significance. Similar studies which confirms education have Positive and significant effect on up taking adaptation methods to the changing climate is observed in Ethiopia (Aemero Tazeze *et al.*, 2012).

Table 4. Sex and educational status of sample households

variables	categorical	CSA adopters (N=84)		Non-adopters (N=63)		X^2 value
		Freq.	%	Freq.	%	
sex	1=male	80	95.2	54	87	4.05**
	0=female	4	4.8	9	13	
Education and experiences	1=Illiterate	10	11.9	36	57.1	40.14***
	2= grade 1-4	20	23.8	15	23.8	
	3= grade 5-8	36	42.9	9	14.3	
	4=grade 9-12	18	21.4	3	4.8	

, * Significance level at $\alpha = 0.05$, and $\alpha = 0.001$ respectively.

Table 5 summarizes the demographic characteristics of continues variables in the study area. As shown below, the mean age of the respondents was 46.43 years. In the study area adopters of CSA practices were younger households (44.61) than non-adopters (48.86). Similarly adopters (5.58) have larger mean family size than non-adopters (5.13). Parallel findings from different regions of Ethiopia and other developing regions (Asrat et al. 2004; Jara-Rojas et al. 2012; Pender and Gebremedhin 2007) who reported a positive relationship between availability of labor force and continued use of stone bunds and other terraces. On the other hand from the entire population, the dependency ratio for the members of the sampled households was estimated to be 0.496, which means every 100 economically active persons had on average 50 extra persons to feed, clothe, educate and medicate.

Table 5. Demographic characteristics of continuous variables for adopter and non-adopters

variable	CSA adopters (N=84)	Non-adopters (N=63)	Total (N=147)	t-value	P value
	Mean+ SD.	Mean+ SD.	Mean +SD.		
Age	44.61+6.23	48.86+8.36	46.43+7.53	3.380***	0.001
Family size	5.58+0.95	5.13+1.14	5.39+1.05	-2.645***	0.009
D. ratio	0.36	0.299	0.496		

*** Significance level at α = 0.001.

Socioeconomic Characteristics of the Households

Households in the study area are engaged in crop production (such as maize, teff, wheat, barley, potato, pea and bean) and livestock rearing (cattle, sheep, goat and chicken). Agricultural production is limited by land in Ethiopia in general and the study area in particular. Therefore, the mean cultivable land sized of households is one factor to decide whether to use modern agricultural technology or not. Based on the survey result adopter households have larger mean land holding size (0.96ha) compared to non-adopters (0.79ha). This indicates that there is an association between the two groups and farmers with greater cultivated land size can have better likelihood to adopt CSA practices compared to smaller landholding size. This study was consistence with (Hassan and Nhemachena, 2014) which states large farm size allows farmers to diversify their crop and livestock options and help spread the risks of loss associated with changes in climate.

Another economic characteristics was the average size of livestock holding in tropical livestock unit (TLU). The mean TLUs for adopters and non-adopter households were 4.38 and 3.16 TLU with standard deviation of 1.01 and 0.85 respectively. From the independent t-test analysis test for equality of variance p=0.044 which is less than the 95% level of significant. This result shows that the H_0 hypothesis is rejected which means the variables have different means in TLU. From this the alpha value (p<0.000) indicating that there is a significant evidence that adoption of CSA practices can be affected by households total livestock unit (TLU). Households with larger TLU have greater likelihood for the adoption of CSA practice. This may be due to some conservational practices introduced on farmlands such as grasses and forage trees can be a source of feed for the livestock. Similar study by (Haftu et.al. 2019), which states households with large number of livestock holding are more willing to continually use SLM practices than those with relatively smaller cattle holdings.

Table 6. Socioeconomic characteristics of adopters and non-adopter HHs

variable	CSA adopters (N=84)	Non-adopters (N=63)	Total (N=147)	t-value	P value
	Mean±SD.	Mean± SD.	Mean ±SD.		
TLU	4.38±1.01	3.16±0.85	3.58±1.12	-7.930***	0.000
LAND_Ha	0.96±0.39	0.79±0.41	0.89±0.40	-2.573**	0.011

,* Significance level α = 0.05. α = 0.001 respectively. This was tasted using *independent-sample t test* is used to compare two groups' scores on the same variable.

Institutional Characteristics of the Household

In addition to demographic and socioeconomic characteristics, institutional characteristics are the main factor for adoption of climate change adaptation strategies and technologies to smallholder farmers. Extension service from agricultural experts to farmers in general play an important role in creating agricultural knowledge and skill to use modern farm technologies. From the entire sample population, farmers who have contact to government extension service once in week were (33.3%), once in two week (30.6%) and once in a month (36.1%). Similarly when we see the extension service provided for CSA adopters and non-adopters independently, more than half of the adopter sample households got extension service once in a week, one-third of them had got once in 15 days while only one-sixth of adopters had got the extension service once in a month. On the other hand less than one-tenth of non-adopter households had got once in a week, one-third had got once in two weeks and near to two-third of the had got only once in a month. Adopter households had got better extension service compared to non-adopter which tells that better extension service can increase the adoption of CSA practices. The result for chi-square test (X^2=41.775 and p=0.000) shows the result is statistically significance and there is an association that adoption of new agricultural technology depends on frequency of extension services provided to local farmer households at 5% significance level.

On the other side, when we look at the participation of households in trainings in the area three-fourth of adopters and one-third of non-adopters have got the chance to training on agricultural practices. In addition to these, more than half of adopters and only one-sixth of non-adopters have got the chance to participate and look CSA demonstration activities. The chi square test ($p<0.000$) shows that there is statistically significance difference and an association between adopters and non-adopters in access of looking CSA demonstration site which have a direct effect in adoption of these practices. Similarly reports which confirm the current study by (Moges and Taye 2017; & Bonger et al 2004), which states extension service has a positive influence on the continuity of SLM practices in central Ethiopia.

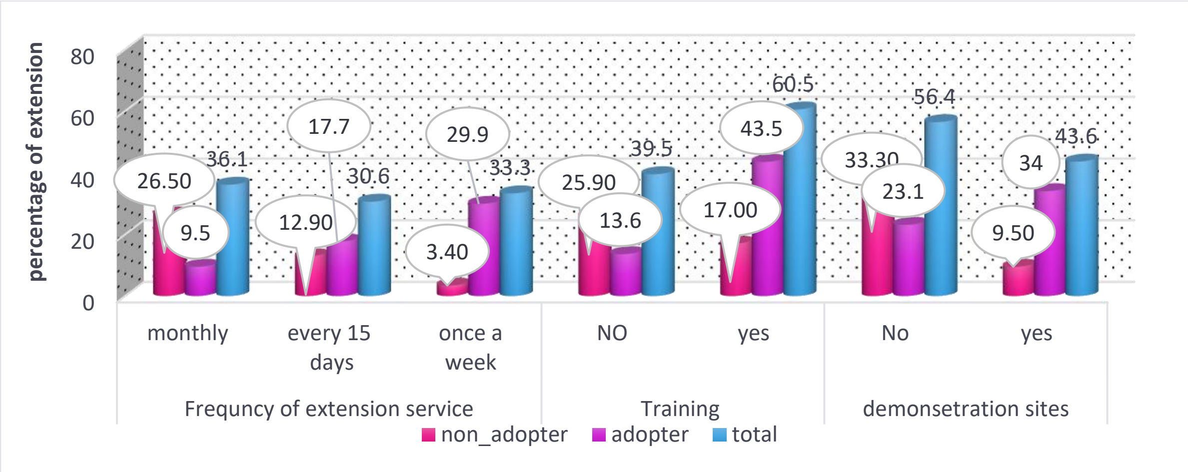

Figure 4. *F*requency percentage of extension given to households.

Another institutional characteristics was access to credit. From the total sample population, 57.8% of households have access to credit while 42.2% of them have no access to it. Around three-fourth of adopters and more than one-third of non-adopter households have access to credit in the last three production years. The chi square test (X^2 =41.76, p<0.000) shows that there is statistically significance difference and an association between adopters and non-adopters in access to credit in the study area. As discussed in focused group discussion and key informant interview, they have got credit from government organization mainly from ACSI for the purpose of mainly purchase of production inputs especially fertilizer and improved crop varieties but high interest rate was a barrier to use credit in the area. Similar study in Chile, for instance, access to credit positively affected the use of soil and water conservation activities (Jara-Rojas et al. 2012). Another study by (Aemro Tazeze *et al.*, 2012) which confirms Credit has a positive and significant impact on likelihood of using adjusting planting date and combination of improved crop variety and crop diversification as adaptation strategies to climate change and variability.

Table 7. The demographic characteristics of categorical variables for adopters and non-adopters (N=147)

variables	categorical	CSA adopters (N=84)		Non-adopters (N=63)		X^2 value
		Freq.	%	Freq.	%	
Credit access	1=yes	62	73.8	23	36.5	20.54***
	0=otherwise	22	26.1	40	63.5	
Access to extension	1=Once/week	44	52.4	5	7.9	41.76***
	2=Once/2 week	26	30.9	19	30.2	
	3=Once/month	14	16.7	39	61.9	
training	1=yes	64	76.2	23	36.5	20.09***
	0=otherwise	20	23.8	40	63.5	
Demonstration	1=yes	48	57.1	10	15.9	20.38***
	0=otherwise	36	42.9	53	84.1	

*** Significant at α= 0.01 and tested using chi square test.

From the above demographic, socioeconomic and institutional characteristics, we can generalize that there was an association and statistical difference between adopters and non-adopter households. This indicates that comparatively male households adopt CSA technologies than female households. Adopter households were better educated, better accessed to credit, extension service, training and having access to look CSA demonstration compared to non-adopters. In addition, adopter households were younger age, larger herd size (TLU), larger family size, and larger cultivated land size compared to non-adopter.

4.2. Main CSA Practices implemented and adopted in the study area

Environmental stresses have always had an impact on agriculture. Farmers have looked for ways to manage these stresses. It also requires developing a set of responses that allow the sector to improve performance under the changing conditions brought about by climate variability. Since, agricultural production remains the main source of income for most rural communities, adaptation of the agricultural sector to the adverse effects of climate variability is imperative for protecting and improving the livelihoods of the poor and ensuring food security (FAO, 2012).

Table 8. Level of participation of major CSA practice implemented and adopted *(N=84)*

major CSA practices	Frequency of participation (%)	X^2
crop rotation with legumes	92.9	24.620***
SWC	89.3	14.064***
Variety diversification	84.5	9.779***
efficient use of artificial fertilizers	75	21.971***
improved crop varieties	73.8	15.865***
organic fertilizer (mainly compost)	67.9	5.212**
changing planting date	64.3	12.432***
Agroforestry practices	58.3	6.862***
irrigation	48.8	8.312***
Inter cropping	41.7	8.468***
Crop residue management	35.7	4.900**
Use of cover Crop/mulching	34.5	3.403*
green manuring	23.8	12.045***

Source own survey 2020 and data from the woreda agricultural office

Soil and water conservation: physical and biological soil and water conservation structures are the most dominant CSA structures which are implemented by most local farmers in the study area. According to the survey result shown 89.3% of the adopter sample households' uses soil and water conservation structures whereas only 10.7% didn't use these structures on their farm land. But as it is observed and discussed to the households, the quality/standard and amount of doing the structures differ between households depending skill gap (education level, accessibility of labor and attitude towards these structures. Soil and water conservational structures are interventions that improve nutrient use efficiency which includes terraces (level and graded bunds (stone bund, stone with soil bund, soil bunds), water harvesting structures mostly trenches and micro basins, gulley rehabilitation and area closer. Biological conservations includes bund stabilizing seedlings like fodder, fruits and multipurpose plants in the harvesting structures and direct sawing of seeds on gulley, bunds and area closers are mostly implemented practices.

According to the focus group discussion and key informant information, these conservational structures have multi advantages to the area even if there are disadvantages raised by the local farmers with regards to reduced cultivated land, stone bunds for house of rodents and need for more labor to do these structures. Even though these disadvantages households were doing these conservational structure to for the purpose of reducing soil erosion and land degradation, important for the percolation of water by reducing the speed and giving time for percolation, changing the gradient of the land if properly managed and generally have a contribution for climate change adaptation. Similar studies by Blanco & lal (2008), which confirms Soil and water conservation structures can provide benefits by reducing water erosion, improving water quality and promoting the formation of natural terraces over time.

Use of crop rotation with legumes: Crop rotation is the practice of growing a series of dissimilar or different types of crops in the same area in sequenced seasons. It is done with legume plants so that the soil of farms is not used for only one set of nutrients. As shown in the graph (5) , 92.9% of the adopter sample households use crop rotation with legumes while only 7.1% use the same type of crop for prolonged time of years at (p=0.000 and X^2=24.620). The large Chi-Square statistic (24.620) and its small significance level ($p <$ .000) indicate that it is very unlikely that these variables are independent of each other.

Thus, we can conclude that there is a relationship between adopters and non-adopters in implementing crop rotation practices in the district.

Growing the same crop in the same place for many years gradually depletes the soil of certain nutrients. In addition, crop rotation mitigates the buildup of pathogens and pests that often occurs when one species is continuously cropped, and can also improve soil structure and fertility by increasing biomass from varied root structures. It helps in reducing soil erosion and increases soil fertility and yield crop. Studies show that it potentially reduces the incidence of weeds and pests, minimizes disease risk (Smith *et al.,* 2015) and improves soil fertility (Hossain *et al.,* 2016). It enhances resilience to multiple environmental stresses.

Crop diversification: - Households adopt various strategies to mitigate the negative effects of production and consumption risks arising from climate variability and extremes. Households in the study area uses crop diversification for the purpose of coping climate risks, to get diversified crop type for consumption and also for which crop the land is suitable to grow (suitability of the plot). According to the study 84.5% of the sample adopter households use crop-livestock diversification in the locality.

Similar findings approves that, Crop diversification boosts crop productivity at the household level by increasing yield (Di Falco et al., 2010; Chavas and Di Falco, 2012). According to this study, Crop diversification can also reduce exposure to weather shocks and increase crop yields through controlling crop diseases and pests. Crop diversification would ultimately reduce the probability of crop failure. By diversifying food crop production, a farm household gains some assurance that it can have something to eat even in the event of crop failure, food price shocks, or lack of food in local markets.

Use of organic fertilizer (mainly compost): Organic fertilizer is usually made from plant or animal waste or powdered minerals by decomposition. The survey result shown in the graph indicates that 67.9% of the adopter sample households prepare and use organic fertilizer (compost) on their farm lands. But they raised the issue of the quality of compost preparation which varies depending on the farmers' willingness and attitude towards the technology and availability of labor. As discussed during group discussion and key informants interview, if they were properly done, organic fertilizers are renewable, sustainable, and environmentally friendly. But the households raise the issue of labor shortage and health related problems during preparation of the organic fertilizers.

Organic fertilizer improves the soil by raising the soil's ability to hold water and nutrients and decreases the erosion and soil crusting caused by rain and wind. Using organic fertilizer adds more natural nutrients, feeds important microbes in the soil and improves the structure of the soil. This means that, unlike chemical fertilizers, organic fertilizers are not easily washed away in a heavy rainstorm or irrigation session, and that the plants get the benefit of nutrients for growth more evenly over a longer period of time rather than all at once.

Use of agroforestry: According to Nair (1993), agroforestry is the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of spatial mixture or sequence so that there must be a significant interaction (positive and/or negative ecological and/or economic) between the woody and non-woody components of the system. Even if the practice is indigenous, the idea of practicing it widely is lately introduced by the SLMPII project to the district. According to the survey data shown in the table (5), 58.3% of the adopter sample households were using agroforestry practices while the remaining 41.7% did not use it. The main agroforestry practice implemented in the study area includes home garden, parkland, hedge row planting, woodlot plantation,

plantation on bunds, etc. Even if the advantages of agroforestry are multi, the participation level of smallholders was not much and it is restricted to some varieties only. But after 7 years after the project started, trainings were given to the farmers to practice the technology. As a result some farmers are shifting to use the technology.

Agroforestry makes conducive environment to the local area and they are the main mitigation practice by reducing emission as well as removal of sinks from the environment. They are economically viable by producing year round source of income. This study consistent with (Luedeling et al. 2014; Coulibaly et al. 2017) which says agroforestry is widely adopted as a climate-smart practice due to its potentials for climate change mitigation, adaptation, crop productivity and food security. Another study also shows that Agroforestry enhances soil organic matter (SOM), agriculture productivity, carbon sequestration, water retention, agro biodiversity and farmers' income (Zomer et al. 2016; Paul et al. 2017).

Use of improved crop varieties: Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development in developing countries. To improve the agricultural productivity and farmers' livelihoods, several agricultural technologies (improved crop and livestock varieties, and related agricultural practices) were introduced by government and various agencies to the farmers in the district. According to the finding farmers are using improved varieties especially most farmers use crop mainly maize, wheat, teff and potato. The data from the survey shows that 73.8% of the sample population uses improved crop varieties in order to increase productivity from their farm land.

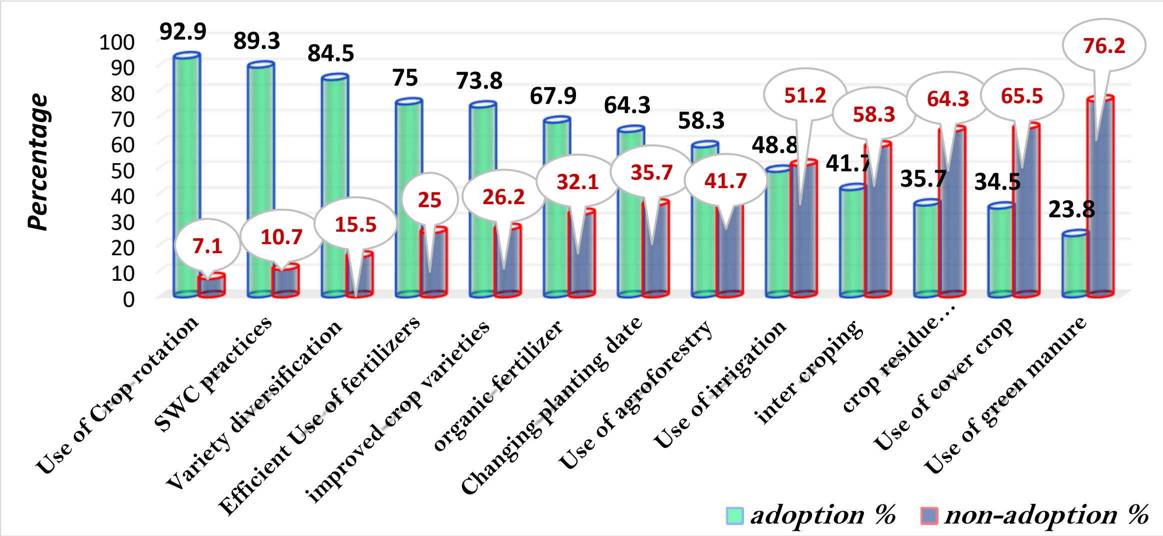

Figure 5: Participation status of households in main CSA practices

From the above result showed crop rotation, SWC practices, variety diversification, use of fertilizer were better adopted while use of green manure, cover crop and crop residual management practices were less adopted practices in the study area. In general as it is known and many findings confirm that these CSA practices have climate change adaptation and mitigation advantages. In addition some practices have also GHG emission reduction and sink effect because of better management and cover of the soil such as agroforestry, residual management, organic fertilizer, cover crops, biological conservational structures. These generally leads to increased productivity and there by increased income of households by reducing the impacts of climate variability to the study area.

4.3. Impact of CSA practices for enhanced productivity and income

4.3.1. Productivity of main crops in the study area

Climate-smart agricultural practices have the potential to sustainably increase agricultural productivity, mitigate environmental degradation, increase farmers' resilience and stimulate inclusive growth (FAO, 2010; United Nations, 2011). Opportunities to safe production space include the adoption of climate-smart agricultural practices that would reduce food loss (e.g. storage innovations), mitigate climate change (e.g. conservation agriculture), and climate change adaptation and yield improvements (e.g. crop diversification, conservation agriculture); (Beddington et al., 2012; Neufeldt et al., 2013). According to MOA (2018), the main aim of RLLP was enhancing the livelihood resilience of beneficiary households through Climate-Smart Agriculture (CSA) interventions in all eligible micro-watersheds assisted by the project. The improved adaptation of restored watersheds to variable rainfall patterns and adverse climatic events, combined with reduced degradation-related risks. This will provide suitable conditions for beneficiaries to adopt improved climate-smart farming practices and diversify and/or intensify their current production systems.

Climate smart agricultural practices are important to reduce run off and soil erosion and also they improve fertility/nutrient and water holding capacity of the soil, then the direct effect will continuously increase productivity and production. From the data shown in figure (6), 98.8% of the total adopter sample population assure that there was an increase in yield in the last three production years because of the implemented CSA practices. Yield increment can be achieved through using the available land in a sustainable ways by using maximum potential with no or less impact for future generation.

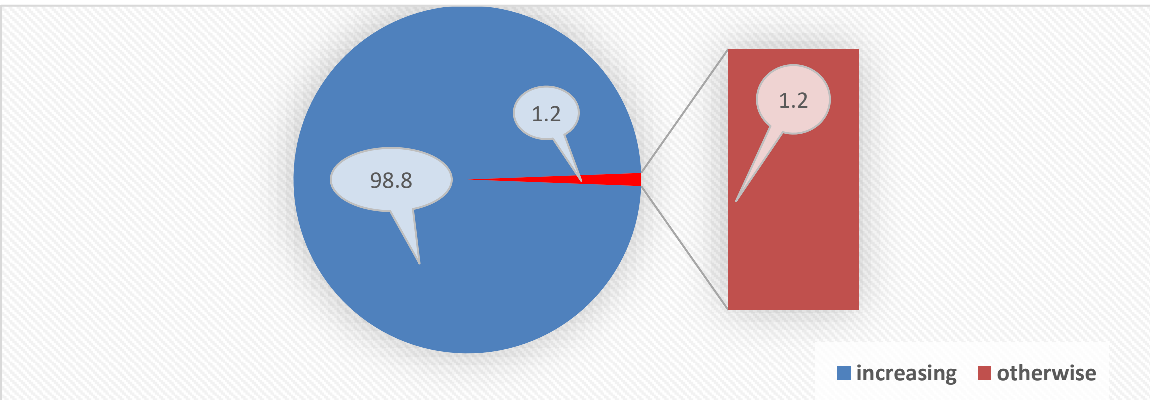

Figure 6. *Percentage of yield trends because of CSA practices in the study area*

As indicated in the table 9 below, the main crops grown are maize, teff, wheat, barley, potato and legumes mainly bean and pea. As shown in the table 8, adopters gain significantly larger yield for all crops. The average productivity of maize for adopters and non-adopters was 42.45 and 36.29 qtl/ha respectively. These shows that there is a mean productivity difference between adopters and non-adopters and the difference is statistically significant at 99% level of significant. These may be due to the fact that, CSA practices can improve soil fertility and water holding capacity of the soil which can reduce impacts of climate variability.

Similarly, as shown in the table 8, the increased in productivity for adopters compared to non-adopters for maize, teff, wheat, barley, potato and legume crops was 16.97%, 2.7%, 12.62%, 22.05%, 5.23% and 28.17% respectively. From these legumes, wheat, barley and maize have better mean productivity increment because of adoption of CSA practices. The T test also shows that the difference in productivity between adopters and non-adopters for these crops was significant at 95% level of significant except potato significant at 90% level of significant and teff which is insignificant even at 90%. Similar studies by (Haftu et.al. 2019), which confirms crop yield of households who practiced multiple SLM was found to be higher by 42.8% compared to the non-continued users of SLM practices.

Average income of main crops	CSA adopters (N=84)	Non-adopters (N=63)	t-value	P-value
	Mean ±SD (ha)	Mean ±SD (ha)		
Maize	42.45±5.91	36.29±7.54	-5.371***	0.000

Table 9. Average productivity of main crops by adopters and non-adopters (N=147)

Teff	18.31±2.67	17.83±3.22	-0.893^{NS}	0.374
Wheat	31.14± 5.90	27.65±3.71	-3.277***	0.002
Barley	33.21±4.43	27.21± 2.84	-9.671***	0.000
Potato	149.62±20.41	141.80±12.98	-1.763*	0.084
Legume crops	18.29± 3.26	14.27± 1.64	-8.798***	0.000

*, **, ***, ^{Ns} and α=0.1, α= 0.05, α= 0.01 and not significant respectively with independent t test.

4.3.3. Household income

Household income is derived from agricultural (crop and livestock) sales and value of crops and livestock products retained for household consumption. The value of retained crop and livestock products was calculated using annual average production prices. The off-farm and non-farm incomes were also computed as part of household income to evaluate the income difference between adopter and non-adopter households due to CSA practices.

Income from crop production:- the main crops grown in the study area are maize, teff, wheat, barley, potato and legumes (like bean, pea chickpea). The first main crop grown in the study area was maize and the mean income gained from adopter and non-adopter sample households was 17088.9 and 15144.3 ETB respectively. As it is shown there is a difference in mean income from maize between adopters and non-adopters where mean income of adopters was greater than that of non-adopters. The significant level also shows that p-value ($p<0.024$) which is significant at alpha p-value ($p<0.05$) indicating that there was statistically difference in mean income between adopters and non-adopters. This may be due to the fact that CSA technologies can enhance crop productivity by reducing the impacts of climate change and improving the soil fertility through different practices.

Another main crop in the study area was barley where the mean income gained from it for each sample households of adopters and non-adopters was 5765.7 and 3484.1 respectively. There is a difference in mean income gained from barley as the income for adopter was greater compared to non-adopters. The significant level ($p<0.000$) which is less than the alpha p-value ($p<0.05$), indicating that there was statistically different between mean of income from barley at 95% level of significant.

The other main crop was teff and wheat where the mean income gained from it for adopters was 5320.6 and 3251.5 while the mean income for non-adopters was 5670.9 and 1603.3 respectively. There was a difference in mean income from teff and wheat between adopters and non-adopters. Adopter got larger mean income from wheat and there was statistical difference at 95% level of significant ($p<0.000$).

Lastly the other crops which are very important for crop rotation are legumes which includes bean, pea and chickpea. As indicated in table 10 below, the mean income gained from legume crops in general for adopters and non-adopters was 2817.9 and 1500.9 respectively. This shows there is a difference in mean income gained between adopters and non-adopters and the difference was statistically significant ($p<0.000$) at alpha p value of ($p<0.05$). These may be due to CSA adopter use more legumes for crop rotation and even adopters use better land management practices which enhances productivity.

Total income from main crops:- as shown in the table 10 below, the mean income from main crops for adopter and non-adopter sample households was 34755.3 and 27865.1 ETB respectively. The result shows that there is a significance mean difference of income from main crops between adopter and non-adopter groups at 5% significance level. This may due to adopter households had manage their farm land better compared to non-adopter households in the study area. The variation in income from crops is explained by the variation in productivity between adopters and non-adopters

Livestock income: Livestock plays a significant role as income sources in rural poor Ethiopia. Sale of live animals and their products (like egg, butter, honey etc) are main livestock-related income sources in the study area. In the study area as discussed during group discussion households had shortage of forage and grazing areas for animal during dry season that enable to increase the quality and stock of livestock. The average livestock income for adopter and non-adopter sample households was 7691.9 and 4967.3ETB respectively. Adopters have got larger mean income from livestock compared to non-adopters to fill the food gap through selling the existing stock of livestock and it was statistically significant at 99% level of significant (Table 10). This may be due to the presence of larger herd size of adopters than non-adopters.

Non/off-farm income: Non/off-farm incomes are important parts of total income in rural households. The income from off-farm income includes daily labor, petty trade, sale of woods mainly eucalyptus and house rent. The average non/off-farm income for adopter and non-adopter sample households was 2541.7 and 839.1 ETB. The result shows that there is a significance mean difference of income from non/off-farm activities between adopter and non-adopter groups at 5% significance level. This is may be due to CSA adopter households had enabled to diversified livelihood strategy through engaged in different off/off-farm income generating activities than non-adopter households.

Total Income of households : incomes in the study area includes income from non-farm/off farm activities, income from crop yield, income from bi-products of livestock and income from sell of livestock's. Crop was the main income source and then livestock and off-farm income for both adopter and non-adopters in the study area. Adopter receive their income 77% from crop, 17% from livestock and 5.6% from off-farm incomes. Non-adopters also gain their income 82.7% from crop, 14.7% from livestock and 2.5% from off-farm activities.

When differentiating means income of adopters and non-adopters, CSA technology adopters were well off in the mean crop incomes, livestock incomes, nonfarm income and total income. The mean income of CSA adopters and non-adopters was 44988.9 and 33671.4 ETB respectively. This results tells that there is an increased in mean income of adopters by 11317.5 ETB which is 33.6% compared to non-adopters because of CSA practices implementation. Adopters are more productive and have greater income than non-adopters shows that CSA practices are more effective in yield increment in the study area.

Similar studies in Vietnam, profits under conventional practice and with under CSA practice shows that there is constitutes an increase in profit of 17% to 41%. This result also in line with studies in Ethiopia by (Haftu et.al. 2019) the average amount of crop yield of continued users of SLM practices was 33.3% higher than that of non-continued users. Similar findings also confirm that conventional techniques when combined with under the precision system, contributed to an increase in net income ~30% increase (Sapkota et al. 2014). Another confirmation also by Olayide (1980) which confirms there was 26%, 37%, 9% and 26% maize yield improvement if farmers did adopt CSA practices such as portfolio diversification, soil and water conservation, soil fertility improvement and irrigation and water harvesting technologies respectively.

Similar studies show that Users of CSA technologies had their plots performing better than plots without CSA technologies. The study also consistent with Tesfaye (2019) which confirms that CA generates higher farm productivity benefits when minimum tillage is used in combination with cereal-legume intercropping, increasing the average crop income by about 5,208 ETB per hectare for users compared to the counter factual scenario of non-use.

Table 10. Average income of adopters and non-adopters from crops (mean +SD) (N=147)

Average income of main crops	Average price	CSA adopters (N=84)	Non-adopters (N=63)	t-value	P value
		Mean +SD (ETB)	Mean +SD (ETB)		
Maize	968	17088.9±5462.9	15144.3±4617.8	-2.280**	0.024
Teff	2438	5320.6±2766.6	5670.9±4220.4	0.573^{NS}	0.568
Wheat	1080	3251.5±2420.1	1603.3±2193.5	-4.250***	0.000
Barley	950	5765.7±1847.6	3484.1±2284.1	-6.494***	0.000
potato	380	510.7±611.7	461.7±756.7	-0.434^{NS}	0.665
Legume crops	2290	2817.9±1216.6	1500.9±1525.9	-5.637***	0.000
Total from crop		34755.3±8244.6	27865.1±9078.5	-4.801***	0.000
Income from livestock		7691.9±5147.6	4967.3±4530.5	-3.341***	0.001
Off farm income		2541.7±4732.9	839.1±2025.4	-2.956***	0.004
Total income		44988.9±10634.3	33671.4±10919.2	-6.313***	0.000

Source: average price for major crops was from Bibugn district trade and industry office.

, * and ^{NS} significant at α= 0.05, α= 0.01 and NS= not significant respectively

4.4. Factors affecting the continued use of CSA practices

The reduced formal used in this logistic regression model is

Y =bo+ b1X1 + b2X2 + b3X3+ b3x3…….b12x12 + εi,

Adoption=1.8(male)-0.051(age)+0.791(F.size)-1.07(DR)+0.868(Edu)+1.937(Ext)+ 2.856(Demo)+ 2.738(Tr)+2.154(Cr.acc)+1.405(TLU)+0.685(LHD)-15.693

The binary logistic regression of the present study confirms that the model is fit and highly significant (Prob > chi2 =0.000). Furthermore, the Hosmer-Lemeshow test of goodness of fit also fails to reject the null hypothesis which indicates that the model is fit to the data (Table 10 below).The results of the binary logit regression show that 7 out of the 12 variables included in the model significantly affected the continued use of CSA practices by rural households. According to the results of Nagelkerke R Square (0.848), it was 95% confident that 84.8% of the variation to dependent variable (adoption) is due to the identified independent variables and only near to 15.2% variation is because of other factors.

Before running the model, the explanatory variables were checked for multicollinearity and degree of association using variance inflation factors (VIF) and contingency coefficient (CC) for all continuous variables and dummy variables respectively. Thus none of the variables were are strongly correlated with each other and used in the analysis. The VIF and CC values of the variables in the model as shown in Appendix 5 and Appendix 6 are less than the critical values showing that there is no problem of multicollinearity.

The coefficient of determination (B) of the Binary logit model provide the direction and magnitude of the effect of explanatory variables on the dependent variable. A positive sign of the logit coefficient indicates that there is an increase in the dependent variable by a unit change in the explanatory variables or more likely to adopt the CSA practice than the non-adopters. The P-value indicates whether the independent variables have a positive or negative statistical significant effect or not to the dependent variables depending on the sign of coefficient of determination. Lastly Odds ratio tells the probability of adopting the CSA technology by smallholder farmers in the study area. In this case an odds ratio of greater than one have higher probability to adoption and a value of less than one indicates reduction in the adoption of the practices but a value of one tells there is no difference for adoption of the technology between adopters and non-adopter households because of the indicated factor.

In spite of the potential of CSA to improve resilience and to enhance agricultural production and rural livelihoods, adoption of CSA practices and technologies is still very limited in Africa for a host of reasons (Adger *et, al*., 2003). Multiple factors influence farmers' decisions to adopt agricultural technologies (Doss, 2003; Kassie et al., 2010; Birthal et al., 2015). A study conducted in north western part of Ethiopia by Adugna and Bekele (2007) revealed that economic variables such as plot ownership, livestock holding, family size, and land-to-labor ratio have an influence on adoption of land conservation practices. World Bank (2007) and Yirga (2007) also reported that institutional factors such as land insecurity, access to credit, proximity to all weather road, and market access were likely to influence the adoption of and investments on sustainable land management practices in Ethiopia. Since this is an important stage as it guides on the necessary interventions to improve the adoption of CSA packages factors in Bibugn district also identified and discussed below.

Gender of the household head: gender have a positive relationship but it has no significant effect on the adoption of CSA technologies. The odds ratio of gender shows that male have the probability to adopt the technology 6.049 times greater likelihood than females keeping other factors constant. The coefficient of determination or marginal effect was 1.800, which indicated that being male household increase the likely to apply CSA practices on their farm by 180%. This can be due to the fact that these technologies needs resource and more labor which require hard work and women are culturally assigned for domestic activities and even have limited access to critical resources (land, cash, and labor), which often undercuts their ability to carry out labor-intensive activities like compost preparation and soil and water conservation. This finding is thus in line with Kebede (2013) and Mihiretu et al.,(2019) , confirming that male farmers are more likely to access information on climate change and pleased to take risks than their counterparts.

Age of household: Households age has a negatively relationship to the adoption of CSA practices but it has no significant effect on the adoption of CSA technologies. The probability of adoption decreases with age of households which is farming experience. The coefficient of determination show that a negative value, which indicates as age of household increased by 1 year, the adoption of CSA technology will be reduced by 5.1% . This finding was confirmed by results of previous studies which showed that older farmers generally lacking interest and incentive to adapt to climate change (Uddin et al., 2014). Empirical studies by Arega et al.(2013) and Gebreyesus (2016) showed that age of the household head negatively related to farmers decision to diversify to non-farm and off-farm activities.

Family size of the household: Family size of the household has a positive relationship but less\no significant effect on the adoption of CSA practices. The results of the study indicated. When the family size especially active labor force increased by 1 person, the probability to adopt CSA practices increased by 2.206 unit by keeping other variables constant. Similarly, when we see coefficient of determination as family size of households increased by 1 person, the likelihood of adoption of CSA practices will be increased by 79.1%. The study was consistent with SHAW (2014) which confirms Households with a larger pool of labor are more likely to adopt improved technologies and use them more intensively because they have fewer labor shortages at peak times. This finding also in line with (Oyekale and Oladele, 2012), which shown that the visible tendency of larger households to adapt to climate change is probably due to their higher endowment of labor.

Dependency ratio: Furthermore, Dependency ratio also have a negative and significant effect on the adoption of CSA technologies at 90% of significant level. As a household have 1 more number of dependency age groups which are not active labor force, the adoption of new CSA technologies will reduced by 107.3%. Similarly the odds ratio tells that comparing the number of dependency ration in the households, households with greater number of DR, the likely to adopt CSA technology will be reduced by a factor of 0.342 units as compared to less dependency ratio.

Education level of the household head: as shown below in table (11), education was positive and significantly related to farmers' decision to adapt to climate smart agricultural practices. The coefficient of determination showed that, as education of households increase by one level, the adoption of new CSA technology will be increased by 86.8% compared to the illiterate households. The Odds ratio also shows that as education of households increased by one unit, the probability to adopt CSA technology increased by 2.381 times as compared to illiterate households. This finding was also in line with (Chander and Thangavelu, 2004) which founds that literate household heads have better capability and knowledge to access and absorb new information, and are more likely to have more non-farm income, which in turn influence the decision to adopt new technology. This finding is covenant with the result of Gebrehiwot (2013) stating that education improved the probability of climate change adaptation through performing crop diversification, soil conservation, changing planting dates and irrigation. The finding also in line with Aryal et al.(2018), and SHAW (2014) Households belonging to the general caste and with a literate head are more likely to adopt the CSA options.

Frequency of contact with the extension agents: As shown in the table (11) below, access to extension service, participating in trainings that creates awareness and looking over demonstration areas all have positive and significant influences on the adoption of CSA technologies by smallholder farmers at 5% level of significant. The coefficient of determination(B=1.937) indicated that as the frequency of extension service given increased by 1 more unit, the likelihood to adopt CSA practices will be increased by 193.7% as compared to farmers with less or no access to extension service assume other factors held constant. This may because of that if a household gets extension service about new technology, it creates awareness and increase willingness to apply it in the farm land. This result confirmed with the findings of Mihiretu et al.,(2019), which states farmers having increased contact frequency with the extension agent would have better prospects to climate change information and various farming practices that they can use to adapt the adverse effects. Another study also confirms that Households further away from extension services are less likely to adopt CSA (Aryal et al.,2018 and (Wekesa et al., 2018)).

Households' access to demonstration sites and training: Both accesses to demonstrations and training about CSA practices have a positive and significant effect on the likelihood of using CSA technologies. If a household have one more access to model demonstration sites and participate in CSA trainings the probability of using CSA practices increase by 285.6 and 273.8% respectively. The reason behind may be Access to practical and theoretical training and demonstration can change the behavior and attitude of households by increasing skill and knowledge about the CSA practices which make them apply the practices on their farm land. This is consistent with (Aryal et al., 2018) which says Training and access to information significantly enhance the adoption of CSA.

Access to credit: The study results showed that the probability of adoption of CSA practices positively and significantly influenced by increased credit access. The coefficient of determination (B=2.154) shows that, as households have access to credit, the probability to adopt new CSA technology will be increased by 215.4% keeping other factors constant. The odds ratio also tells that the probability of technology adoption will be 8.616 times greater than farmers with no access to credit. This result is consistent with previous findings that access to credit is an important variable which commonly has a positive effect on adaptation behavior and thus adaptation to climate change (Fosu-Mensah et al., 2012).

TLU: According to the result shown in table (11) below, TLU have a positive and significant implication on the adoption of CSA technologies at 95% level of significant. As a house hold have one more TLU, the probability to adopt CSA technology will increased by 4.074 times as compared to non-adopters other factors hold constant. This could possibly be associated with owning more livestock, as it is a liquid asset and provide financial safe guarding (DFID, 1999). Likewise, this finding was in line with in India, Aryal et al. (2018), revealed that more ownership of livestock showed a higher intensity of adoption of climate-smart agricultural practices.

Farmland size of the household: The effect of farm size on the likelihood of adoption of climate smart agriculture was positively but it is not statistically significant even at 90% level of significant. Hence a one hectare increase in farm size would increases the likelihood of using CSA practices by 68.5% keeping other factors constant. Similarly, when a farmer have 1 more hectare of cultivated land, the probability of likelihood of adoption of CSA technologies will be 1.983 times higher as compared to base line size. This result was Consistent with earlier studies on technology adoption (Kassie *et al.,* 2010, 2013,(Wekesa et al., 2018)) the larger the plot, the higher the probability of adopting different practices

Table 11. Binary logit results for the continued use of CSA practices (N=147)

Independent variables	Coefficient B	Sig.	Odds ratio
sex of household(1)	1.800 NS	0.291	6.049
age of household head	-0.051 NS	0.325	0.950
family household size	0.791 NS	0.100	2.206
Dependency ratio	-1.072*	0.082	0.342
education level of HH	0.868**	0.045	2.381
extension service	1.937***	0.001	6.939
demonstration sites(1)	2.856***	0.003	17.399
training(1)	2.738***	0.002	15.458
Access to credit access	2.154**	0.024	8.616
TLU	1.405***	0.004	4.074
land holding size in ha	0.685**	0.470	1.983
total income	0.000 NS	0.268	1.000
Constant	-15.693		
Model summery	*-2Log likelihood =53.992[a]*	*Cox & Snell R Square=.632*	*Nagelkerke R Square=.848*

Dependent variable= adoption of CSA, target category =1 the reference is 0
Omnibus test of coefficients chi^2= 146.782, df=12, p=0.000,
Hosmer and Lemeshow Test chi-square= 8.244, p=0.410

*, **, ***, NS, *significant at α=0.1, α = 0.05, α = 0.01, NS = Not Significant respectively.*

5. Summery and conclusion

5.1. Summery

This study assessed the adoption of climate smart agricultural practices and its impact to crop productivity and households' income in sustainable land management project in Bibugn district, Amhara Region, Ethiopia. Farmers who adopted climate smart agricultural practices implemented by SLMP had larger farm size and livestock holding than non-adopters. Larger number of adopters attended primary school compared to non-adopter farmers and the earlier were younger than the latter. Furthermore, Adopters had better access to extension and credit access than non-adopters.

Of the implanted climate smart technologies crop rotation, SWC, crop variety diversification, efficient use of fertilizer, organic fertilizer and agroforestry were widely adopted. On the other side intercropping, crop residual management, cover crop, and green manure practices were Lesly adopted in the study area.

According to the result the productivity of main crops for adopters' maize, teff, wheat, barley, potato and legume crops increased by 16.97%, 2.7%, 12.62%, 22.05%, 5.23% and 28.17% respectively as compared to non-adopters. From the total mean annual income of a household, cropping contributes the highest income share (79.2%) followed by livestock (16.4%) and off-farm (4.4%), respectively. Adopters achieved significantly larger crop productivity and earn significantly higher income than the non-adopters. These have resulted in higher crop yields and increased in mean income of adopters by 11317.5 ETB which is 33.6% increase compared to non-adopters because of CSA practices implementation.

Different factors influence households from applying CSA practices to their cultivated land. According to the result from binary logistic regression model education level of households, access to extension service, credit access, trainings, demonstration and TLUs have a significant and positive influence on adoption of CSA technologies. But dependency ratio have negative and significant effect on adoption of CSA practices at 90% level of significant.

5.2. Conclusion

According to the key findings from the study, the following points are recommended for further consideration and improvement.

- As non-adopters have less access to extension service, low access to credit, less participation in training and less access to participate in sharing of experience like looking for demonstration. Therefore, responsible organization should take over the responsibility to create awareness and build their capacity for full participation in development agendas and in implementation of improved agricultural technologies.
- To improve the demand and implementation of CSA practices, farmers should be motivated to join and participate in different training and demonstration areas so that they could share farming information and increase their knowledge.
- Non-adopters have less crop productivity and income than adopters. These is due to continues use of CSA practice by adopters on their far land. Therefore, the government and other responsible bodies should have to work to create awareness on the impacts of climate change and different adaptation strategies which can have the potential to sustainably increase productivity and income.

- Also create awareness and build the capacity of smallholder farmers to engage in alternative income generating activities for farmers to benefit more from CSAs climate smart agricultural practices.
- Finally, NGO's and GO's should take the initiative to scale up implementation of CSA practices on different agro ecological areas to reduce impacts of climate change and to increase the adaptive capacity of stallholder farmers.

Reference

Adesina, A.A. and Baidu-Forson, J., 1995. Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. Agricultural economics, 13(1), pp.1-9.

Adesina, A.A. and Chianu, J., 2002. Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. Agroforestry systems, 55(2), pp.99-112.

Adger, W, Huq, S, Brown, K, Conway, D, and Hulme, M (2003) "Adaptation to Climate Change in the Developing World" Progress in Development Studies.

Adugna G, Bekele W (2007) Determinants of land degradation in the Lake Tana Basin and its implications for sustainable land management. The Case of Angereb And Gish-Abbay Watersheds

Adugna, T, Gazahgne, A, Mengistu K, and Endrias G, (2013). Adaptation to climate change and variability in Eastern Ethiopia. Journal of Economics and Sustainable Development,

Aemro Tazeze, Haji Jemma and Ketema Mengistu. 2012. Climate change adaptation strategies of smallholder farmers: the case of Babilie district, East Hararghe zone of Oromia regional state of Ethiopia. *Journal of Economics and Sustainable Development*.

Agrawal, A., M. Kononen, and N. Perrin. 2009. The Role of Local Institutions in Adaptation to Climate Change. Social Development Working Papers. Paper No. 118/June 2009. The World Bank. Washington DC.

Aragie, E. A. (2013). Climate change, growth, and poverty in Ethiopia. TEXAS UNIV AT AUSTIN.

Araya, A., & Stroosnijder, L. (2011). Assessing drought risk and irrigation need in northern Ethiopia. Agricultural and Forest Meteorology.

Araya, T., Cornelis, W. M., Nyssen, J., Govaerts, B., Getnet, F., Bauer, H.,Deckers, J. (2012). Medium-term effects of conservation agriculture based cropping systems for sustainable soil and watermanagement and crop productivity in the Ethiopian highlands.

Arega B, Woldeamlak B, Melanie N. Rural households' livelihood assets, strategies and outcomes in drought-prone areas of the Amhara Region, Ethiopia: case study in Lay Gaint District. Afr J Agric Res. 2013.

Arslan, A., Cavatassi, R., Alfani, F., Mccarthy, N., Lipper, L., and Kokwe, M. (2018). Diversification under Climate Variability as Part of a CSA Strategy in Rural Zambia. Journal of Development Studies.

Aryal, J.P.; Jat, M.; Sapkota, T.B.; Khatri-Chhetri, A.; Kassie, M.; Rahut, D.B.; Maharjan, S. 2018. Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. Int. J. Clim. Chang. Strateg. Manag.

Asfaw S., Di Battista F., and Lipper L. (2014). Food security impact of agricultural technology adoption under climate variability: micro-evidence from Niger. *ESA Working Paper*. No. 14-12. Rome, FAO.

Asfaw, S., Pallante, G., and Palma, A. (2018). Diversification strategies and adaptation deficit: Evidence from rural communities in Niger. World Development.

Asmame, B. M., & Abegaz, A. Y. (2017). Determinants of farmers' adoption of land management practices in Gelana sub-watershed of Northern highlands of Ethiopia. Ecological Processes, 6(1), 19. https://doi.org/10.1186/s13717-017-0085-5.

Asrat P, Belay K, Hamito D (2004) Determinants of farmers' willingness to pay for soil conservation practices in the southeastern highlands of Ethiopia. Land Degrad Dev.

Asrat, P., & Simane, B. (2018). Farmers'perception of climate change and adaptation strategies in the Dabus watershed,North-West Ethiopia. Ecological Processes.

Barnard, J., Manyire, H., Tambi, E., Bangali, S., 2015. Barriers-to-scaling-up-out-CSA-in-Africa.pdf.

Baumgärtner, S. and Quaas, M. F. (2010). Managing increasing environmental risks through agrobiodiversity and agrienvironmental policies. Agricultural Economics.

Beddington, J. R., Asaduzzaman, M., Clark, M. E., Bremauntz, A. F., Guillou, M. D., Jahn, M. M., Lin, E., Mamo, T., Negra, C., Nobre, C. A., et al. (2012). The role for scientists in tackling food insecurity and climate change. Agriculture & Food Security.

Befekadu, D. and Berhanu, N. 2000. Annual Report on the Ethiopian Economy, Vol. I. The Ethiopian Economic Association.

Benin, S. 2006. Policies and Programs Affecting Land Management Practices, Input Use, and Productivity in the Highlands of Amhara Region, Ethiopia. In *Strategies for Sustainable Land Management in the East African Highlands*, edited by J. Pender, F. Place, and S. Ehui. Washington, DC: IFPRI.

Beyene, T. 2018. Adoption of climate smart agricultural practices: determinants and challenges in gerar jarso district of oromia regional state, Ethiopia.

Birthal, P.S., Kumar, S., Negi, D.S. and Roy, D. (2015), "The impacts of information on returns from farming: evidence from a nationally representative farm survey in India", Agricultural Economics, Vol. 46 No. 4. pp. 549-561.

Blanco, H. and R. Lal. 2008. Principles of soil conservation and management. New York; springer

Bonger T, Ayele G, Kumsa T (2004) Agricultural extension, adoption, and diffusion in Ethiopia, Ethiopian Development Research Institute (EDRI) Research Report, No. 1. EDRI, Addis Ababa

BWAOP (2019). Bibugn District Agriculture Office annual plan.

BWAOP (2019). Bibugn District Agriculture Office annual report.

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

Bridal, A.B., Owiyo, T. and Sokona, Y., 2013. Loss and damage from the double blow of flood and drought in Mozambique. International Journal of Global Warming, 5(4), pp.514-531.

Campbell B, Thornton P. 2014. How many farmers in 2030 and how many will adopt climate resilient innovations? CCAFS Info Note. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen.

Caswell, M., Fuglie, K.O., Ingram, C., Jans, S. and Kascak, C., 2001. Adoption of agricultural production practices: lessons learned from the US Department of Agriculture Area Studies.

Chander, P. and Thangavelu, S.M. (2004), "Technology adoption, education and immigration policy", Journal of Development Economics, Vol. 75 No. 1, pp. 79-94.

Chavas, J.-P. and Di Falco, S. (2012). On the Productive Value of Crop Biodiversity: Evidence from the Highlands of Ethiopia. Land Economics.

Chazovachii, B., 2012. The Impact of Small Scale Irrigation Schemes on Rural Livelihoods: The Case of Panganai Irrigation Scheme Bikita District Zimbabwe.

CIA, 2015. Research Paper: Climate Change and Resource Sustainability - An Overview for Actuaries.

Cochran, W. G. 1977. *Sampling techniques* (3rd.ed.). New York: John Wiley & Sons.

Coulibaly JY, Chiputwa B, Nakelse T, Kundhlande G (2017) Adoption of agroforestry and the impact on household food security among farmers in Malawi.

CRGE, 2011. Ethiopia Climate Resilient Green Economy Strategy (CRGE). 2011.

CSA (Central Statistical Agency of Ethiopia). 2011. Large and medium scale commercial farm survey 2010/11. Results at country and regional levels.

CSA, 2013. Large and medium scale commercial farm survey 2012/13. Results at country and regional levels.

CSA, 2017. Large and medium scale commercial farm survey 2016/17. Results at country and regional levels.

Dercon, S. (2004). Growth and shocks: Evidence from rural Ethiopia. Journal of Development Economics.

Deressa, T. (2006). Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. CEEPA Discussion Paper No. 21. South Africa: CEEPA, University of Pretoria.

DFID of UK. Sustainable Livelihoods Guidance Sheets; DFID: London, UK, 1999; p. 445.106.

Di Falco, S., Bezabih, M., and Yesuf, M. (2010). Seeds for livelihood: Crop biodiversity and food production in Ethiopia.

Di Falco, S. and Veronesi, M. (2013). How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia.

Dillon, A., 2011. The Effect of Irrigation on Poverty Reduction, Asset Accumulation, and Informal Insurance: Evidence from Northern Mali.

Doss, C.R. (2003), Understanding Farm Level Technology Adoption: lessons Learned from CIMMYT's Micro Surveys in Eastern Africa, CIMMYT, Mexico, DF.

Etsay, H., Negash, T.and Aregay, M., 2019. Factors that influence the implementatioof sustainable land management practices by rural households in Tigray region Ethiopia

Elder, S. 2009. Sampling methodology: A Methodological Guide, Module 3, International Labor Organization, Geneva.

Fanadzo, M., 2012. Revitalisation of smallholder irrigation schemes for poverty alleviation and household food security in South Africa: https://doi.org/10.5897/AJARX11.051

FAO (Food and Agricultural Organization), 2010. Climate-smart agriculture: Policies, practices and financing for food security, adaptation and mitigation.

FAO. 2012. Mainstreaming climate-smart agriculture into a broader landscape approach. Second Global Conference on Agriculture, Food Security and Climate Change Hanoi. Vietnam, 3-7 September 2012: 26.

FAO (2013). Climate-Smart Agriculture Sourcebook. Food and Agriculture Organization of the United Nations.

FAO (Food & Agriculture Organization), 2015. Rapsomanikis, G., 2015. The economic lives of smallholder farmers: An analysis based on household data from nine countries.

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

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

Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. 2012. Farmers' perceptions and adaptation to climate change: a case study of Sekyeredumase district in Ghana. Environment, Development and Sustainability.

Frankema, E. (2014). Africa and the green revolution a global historical perspective. NJAS-Wageningen Journal of Life Sciences.

Gao, J. and Mills, B. F. (2018). Weather Shocks, Coping Strategies, and Consumption Dynamics in Rural Ethiopia.

Garnett, T., Appleby, M., Balmford, A., Bateman, I., Benton, T., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., et al. (2013). Sustainable intensification in agriculture: premises and policies.

Garson, David, (2008) Logistic_Regression.pdf, North Carolina State University.Available at: http://www2.chass.ncsu.edu/garson/PA765/logistic.htm. Accessed on Aug 2017

Gbegeh, B. D. & Akubuilo, C. J. (2012). Socioeconomic determinants of adoption of yam minisett by farmers in Rivers state, Nigeria. *Wudpecker Journal of Agricultural Research*.

Gbegeh, B. D. & Akubuilo C. J. C. (2013). Socioeconomic Determinants of Adoption of Yam 63 Minisett by Farmers in Rivers State, Nigeria. Journal of Agricultural Research.

Gbetibouo, G.A., 2009. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa (Vol. 849).

Gebrehiwot, T., & van der Veen, A. (2013). Farm level adaptation to climate change: The case of farmer's in the Ethiopian Highlands.

Gebreyesus B. (2016). Determinants of livelihood diversification: the case of Kembata Tambaro Zone, Southern Ethiopia.

Gerber, P., Vellinga, T., Opio, C., Henderson, B. and Henning, S. 2010. Greenhouse Gas Emissions from the Dairy Sector life cycle assessment food and agriculture organization of the United Nations, Animal production and health division Report, Rome.

Godfray, H. C. J. and Garnett, T. (2014). Food security and sustainable intensification. Philosophical Transactions of the Royal Society of London.

Gujarati, D. 2004. Basic Econometrics. 4th ed. McGraw-Hill Book Co., 1024p.

Hossain, M.S., Hossain, A., Sarkar, M.A.R., Jahiruddin, M., Teixeira da Silva, I.A., Hossain, M.I., 2016. Productivity and soil fertility of the rice-wheat system in the High Ganges River Floodplain of Bangladesh is influenced by the inclusion of legumes and manure.

IPCC, 2007. Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R., Davidson, O., Hare, W., Huq, S., Karoly, D., Kattsov, V. and Kundzewicz, Z., 2007. IPCC, 2007: climate change 2007: synthesis report. Contribution of working groups I. II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC, 2012: Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC).

IPCC, 2014. Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects. Cambridge University Press.

Jara-Rojas R, Boris E, Ureta B, Díaz J (2012) Adoption of water conservation practices: a socioeconomic analysis of small-scale farmers in Central Chile. Agric Syst 110:54–62

Jat, R.K., Sapkota, T.B., Singh, R.G., Jat, M.L., Kumar, M. and Gupta, R.K., 2014. Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: yield trends and economic profitability. Field Crops Research, 164, pp.199-210.

Jirata, M., Grey, S., Kilawe, E., 2016. Ethiopia Climate-Smart Agriculture Scoping Study.

Jones, P.G. and Thornton, P.K. 2008. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. Environmental Science and Policy.

Juma, C., Tabo, R., Wilson, K., and Conway, G. (2013). Innovation for Sustainable Intensification in Africa. Montpellier Panel Briefing, Agriculture for Impact, London.

Kamara, A.., van Koppen, B. and Magingxa, L. 2002. Economic viability of small-scale irrigation systems in the context of state withdrawal: the Arabie Scheme in the Northern Province of South Africa.

Kassam, A., Friedrich, T., Shaxson, F. and Pretty, J. 2009. The spread of Conservation Agriculture: justification, sustainability and uptake. International Journal of Agricultural Sustainability

Kassie, M., Pender, J., Yesuf, M., Kohlin, G., Bluffstone, R., & Mulugeta, E. (2007). Impact of soil conservation on crop production in the Northern Ethiopian Highlands. (*IFPRI Discussion Paper 00733*). Washington, DC: International Food Policy Research Institute.

Kassie, M., J. Pender, M. Yesuf, G. Köhlin, R. Bluffstone, and E. Mulugeta. 2008. Estimating Returns to Soil Conservation Adoption in the Northern Ethiopian Highlands.

Kassie, M., Holden, S., Köhlin, G., & Bluffstone, R. (2009). Economics of soil conservation adoption in high-rainfall areas of the Ethiopian Highlands. (*Environment for Development Discussion Paper Series DP 08-09*). Addis Ababa, Ethiopia: Environment for Development.

Kassie, M., Zikhali, P., Pender, J. and Köhlin, G. (2010), "The economics of sustainable land management practices in the Ethiopian highlands", Journal of Agricultural Economics, Vol. 61 No. 3, pp. 605-627.

Kassie, M., Zikhali, P., Pender, J. and Köhlin, G. (2011), Sustainable Agricultural Practices and Agricultural Productivity in Ethiopia: Does Agroecology Matter?

Kassie M, Jaleta M, Shiferaw B, Mmbando F, Mekuria M (2013) Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania.

Kassie, M., Teklewold, H., Marenya, P., Jaleta, M., and Erenstein, O. (2015). Production Risks and Food Security under Alternative Technology Choices in Malawi: Application of a Multinomial Endogenous Switching Regression. Journal of Agricultural Economics.

Kebede, G. (2013). Spatial and temporal uncertainty of rainfall in arid and semi-arid areas of Ethiopia. Science, Technology and Arts Research Journal.

Kitalyi, A., Nyadzi, G., Lutkamu, M., Swai, R. and Gama, B., 2010. New climate, new agriculture: how Agroforestry contributes to meeting the challenges of Agricultural development in Tanzania. Tanzania Journal of Agricultural Sciences.

Kristiansen, S. (2011). Climate Change Impacts and Adaptations among Ethiopian Farmers. Legesse, B., Y. Ayele, W. Bewket. Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. Asian Journal of Empirical Research.

Legesse Leta, 2018. Impact of Small Scale Irrigation on Household Farm Income and Asset Holding: Evidence from Shebedino District, Southern Ethiopia.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R., 2014. Climate-smart agriculture for food security. Nature climate change, 4(12), p.1068.

Lobell, D.B., Sibley, A. and Ortiz-Monasterio, J.I., 2012. Extreme heat effects on wheat senescence in India. Nature Climate Change, 2(3), p.186.

Loison, S. A. (2015). Rural Livelihood Diversification in Sub-Saharan Africa: A Literature Review. Journal of Development Studies.

Luedeling E, Kindt R, Huth NI, Koenig K (2014) Agroforestry systems in a changing climate challenges in projecting future performance.

Majiwa, E., Lee, B. L., and Wilson, C. (2018). Increasing agricultural productivity while reducing greenhouse gas emissions in sub-Saharan Africa: myth or reality?

Marenya, P.P. and Barrett, C.B., 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya.

Marenya, P., Kassie, M., Jaleta, M., Rahut, D., and Erenstein, O. (2015). Adoption of Conservation Agriculture under Alternative Agricultural Policy and Market Access Indicators: Evidence from Eastern and Southern Africa.

Mekuriaw, A., Heinimann, A., Zeleke, G., & Hurni, H. (2018). Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. International Soil and Water Conservation Research, 6, 23e30. https:// doi.org/10.1016/j.iswcr.2017.12.006.

Mihiretu et al., Cogent Environmental Science (2019), 5: 1636548Determinants of adaptation choices to climate change in agro-pastoral dry lands of Northeastern Amhara, Ethiopia

MoALR (Ministry of Agriculture and Livestock Resource) (2018). Sustainable Land Management Program Resilient Landscape and Livelihood Project (RLLP) Updated Social Assessment

Moges DM, Taye AA (2017) Determinants of farmers' perception to invest in soil and water conservation technologies in the North-Western highlands of Ethiopia. International Soil and Water Conservation Research 5:56–61

NAPA (National Adaptation Plan for Action). (2007). Climate Change NAPA of Ethiopia. Addis Ababa: MoWER and NMA, Ethiopia.

Nair P. R, (1993). An introduction to agroforestry. Springer Science & Business Media.

Nelson, R.R. and Phelps, E.S., 1966. Investment in humans, technological diffusion, and economic growth. The American economic review, 56(1/2), pp.69-75.

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

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

Nhemachena, C., Hassan, R. and Chakwizira, J. 2014. Analysis of determinants of farm level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics* 6(5) 232-241.

Nkamleu, G.B. and Manyong, V.M., 2005. Factors affecting the adoption of agroforestry practices by farmers in Cameroon. Small-scale forest economics, management and policy, 4(2), pp.135-148.

Nkonya, E., Pender, J., Kaizzi, K.C., Kato, E., Mugarura, S., Ssali, H. and Muwonge, J., 2008. Linkages between land management, land degradation, and poverty in Sub-Saharan Africa: The case of Uganda (Vol. 159). Intl Food Policy Res Inst.

NMA (National Meteorological Agency). 2007. Climate change national Adaptation Programme of Action (NAPA) of Ethiopia, Addis Ababa Ethiopia.

Nyasimi, M., Amwata, D., Hove, L., Kinyangi J. and Wamukoya, G. 2014. 'Evidence of impact: Climate-smart agriculture in Africa'. CCAFS Working Paper no. 86.

Obalum, S.E., G. Ezenne, Y. Watanabe, and T. Wakatsuki. 2011. Contemporary global issue ofrising water scarcity for agriculture: The quest for effective and feasible soil moisture and free-water surface conservation strategies. Journal of Water Resource and Protection

Olayide, S.O. (1980). Characteristics, problems and significance of farmers. 'In' S.O. Olayide, J.A. Eweka and V.E. Bello- osagie (eds): Problems and Prospects in Integrated Rural development, Ibadan. Centre for Agricultural and Rural Development (CARD) 11-14..

Owour, G. & Bebe, B. O. (2012). Determinants of Adoption of Management Interventions in Indegenous Chicken Pproduction in Kenya. *African Journal of Resources Economics*.

Oyekale, A.S.; Oladele, O.I. 2012. Determinants of climate change adaptation among cocoa farmers in southwest Nigeria. ARPN Journal of Science and Technology.

PANW. 2012. Crop rotation benefiting farmers, the environment and economy. Friends of the Risin Earth Europe, EU group and APRODEV.

Parvan, A., 2011. Agricultural technology adoption: Issues for consideration when scaling-up. The Cornell Policy Review, 1(1), pp.5-32.

Paul C, Weber M, Knoke T (2017) Agroforestry versus farm mosaic systems: comparing land-use efficiency, economic returns and risks under climate change effects.

Pender, J. & Gebremedhin, B. (2006). Land management, crop production, and household income in the highlands of Tigray, Northern Ethiopia: An econometric analysis. In J.Pender, F.Place, & S.Ehui (Eds.), *Strategies for sustainable land management in the East African highlands*. Washington DC, USA: International Food Policy Research Institute, pp. 107–139.

Pender J, Gebremedhin B (2007) Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigrai, Ethiopia. J Afr Econ 17:395–450

Polson, R.A. and Spencer, D.S., 1991. The technology adoption process in subsistence agriculture: the case of cassava in southwestern Nigeria. Agricultural systems, 36(1), pp.65-78.

Prasanna, V., 2014. Impact of monsoon rainfall on the total food grain yield over India. Journal of earth system science, 123(5), pp.1129-1145.

Pretty, J., Toulmin, C., and Williams, S. (2011). Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability.

Rogers, E.M., 2003. Elements of diffusion. Diffusion of innovations, 5(1.38).

Sapkota TB, Majumdar K, Jat ML, Kumar A, Bishnoi DK, McDonald AJ, Pampolino M. 2014. Precision nutrient management in conservation agriculture based wheat production of Northwest India: Profitability, nutrient use efficiency and environmental footprint.

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

Shanahan, M., Shubert, W., Scherer, C. and Corcoran, T., 2013. Climate change in Africa: a guidebook for journalists. UNESCO.

SHAW, C.S., 2014. (shaw) agricultural technology adoption in west africa.

Shiferaw, B. and Holden, S.T., 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa.

Shields, P. M. and Tajalli, H. 2006. Intermediate Theory: The Missing Link in Successful Student Scholarship. Journal of Public Affairs Education

Singh, G., Mishra, D., Singh, K. and Parmar, R., 2013. Effects of rainwater harvesting on plant growth, soil water dynamics and herbaceous biomass during rehabilitation of degraded hills in Rajasthan, India. Forest ecology and management, 310, pp.612-622.

Smith, V.H., McBride, R.C., Shurin, J.B., Bever, J.D., Crews, T.E., Tilman, G.D., 2015. Crop diversification can contribute to disease risk control in sustainable biofuels production.

Stern, N. (2007). The Economics of Climate Change: the Stern Review. Cambridge University Press, Cambridge, UK

Sunding, D. and Zilberman, D., 2001. The agricultural innovation process: research and technology adoption in a changing agricultural sector. Handbook of agricultural economics, 1, pp.207-261.

Tambo, J. A. and Mockshell, J. (2018). Differential Impacts of Conservation Agriculture Technology Options on Household Income in Sub-Saharan Africa.

Taneja, G., Pal, B.D., Joshi, P.K., Aggarwal, P.K. and Tyagi, N.K., 2014. Farmers' preferences for climate-smart agriculture: an assessment in the Indo-Gangetic Plain (Vol. 1337). Intl Food Policy Res Inst.

Teklewold, H., Kassie, M., Shiferaw, B. & Kohlin, G. (2013). Cropping system diversificatio, conservation tillage and modern seed adoption in Ethiopia: Impacts on househod income, agrochemical use and demand for labor. Journal of Agricultural Economics.

Tesfaye, 2019. Essays on the impacts of climate-smart agricultural innovations on household welfare: maastricht university. https://doi.org/10.26481/dis.20190327wt

Uaiene, R.N., Arndt, C. and Masters, W.A., 2009. Determinants of agricultural technology adoption in Mozambique. Discussion papers, 67.

Uddin, M.N.; Bokelmann, W.; Entsminger, J.S. 2014. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: a farm level study in Bangladesh.

UNFCCC, F., 2007. Climate change: impacts, vulnerabilities and adaptation in developing countries. Bonn, Germany: United Nations Framework Convention on Climate Change.

United Nations (2011). World economic and social survey 2011: The great green technological transformation. Technical report, United Nations UN DESA, New York.

USAID. 2017. Climate-Smart Agriculture in Ethiopia. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID), Washington, D.C. 26 p

Vermeulen, S.J., Campbell, B.M. and Ingram, J.S., 2012. Climate change and food systems. Annual review of environment and resources, 37.

Wekesa, B.M., Ayuya, O.I., Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. Agric. Food Secur. 7. https://doi.org/10.1186/s40066-018-0230-0

Woldegebrial, Huylenbroeck, G.V., Hidgot, A., Chandrakanth, M.G., Speelman, S., 2015. Adoption of Small-Scale Irrigation and Its Livelihood Impacts in Northern Ethiopia: Agricultural Economics, Food Security, Propensity Score Matching.

Wondifraw ZA, Kibret H,aile, Wakaiga J. 2014. Ethiopia 2014. African Development outlook 2015. AfricanEconomicOutlook.org, Moulineaux, France.

Woodfine, A. 2009. The Potential of Sustainable Land Management Practices for Climate Change Mitigation and Adaptation in Sub-Saharan Africa.

World Bank (2006). Ethiopia: Managing water resources to maximize sustainable growth. (Report No. 36000-ET). Washington, DC: The World Bank

World Bank (2007). Ethiopia Climate fact Sheet: site resources. worldbank.org//Ethiopia_Country _Note.pdf

World Bank (2008). *The Agenda for Agriculture Based Countries of Sub-Saharan Africa*. World Development Report, Agriculture for Development.

Worled bank, 2011. Climate-Smart Agriculture: Increased Productivity and Food Security, Enhanced Resilience and Reduced Carbon Emissions for Sustainable Development-Opportunities and Challenges for a Converging Agenda: Country Examples. World Bank, Washington, DC.

Yirga C (2007) The dynamics of soil degradation and incentives for optimal management in central highlands of Ethiopia. Unpublished Ph.D. thesis. Department of Agricultural Economics, Extension, and Rural Development. University of Pretoria, South Africa.

Zomer RJ, Neufeldt H, Xu J, Ahrends A, Bossio D, Trabucco A, van Noordwijk M, Wang M (2016) Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets.

APPENDICES

Appendix 1. Household Survey Questionnaire

My Name is Lakachew Limenih. I am a student at Hawassa University doing my MSc. Degree in Climate Smart Agriculture and Landscape Assessment. I am conducting my master's thesis on Assessment of Effectiveness of Climate Smart Agriculture Practices of Farmers in Sustainable Land Management Project in Bibugn district, Amhara Regional State, Ethiopia. Dear respondents, you are one among several farmers in this area who have been selected for this study. The study seeks to evaluate the implementation of Climate Smart Agricultural practices and its effect on household income. The result of this study will help different stakeholders and policy makers to make appropriate measures on the choice of multiple and effective Climate Smart Agricultural practice in the future. The information you will give will be strictly confidential. Therefore, you are kindly requested to provide genuine responses. Thank you for your time and cooperation!

Instruction

- Where choices are available in the below question try to encircle.
- Where choices are unavailable try to give the answer on the space provided.

1. General information of household

1.1. Region: Amhara , Zone: East Gojjam, District: Bibugn
Survey kebele ……………… village ……………
1.2. Name of enumerator………………Date ………Signature……Questionnaire code……
1.3. Participant status: 1 = CSA practices adopter, 0 = non- adopters
1.4. Checked by ……… ………………. Date …………….signature ……….
2. Respondents demographic information
2.1. Name of household ……………………………………………
2.2. Sex of household head: 1 = male, 0 = female
2.3. Age of household head: ……… (Year)
2.4. Educational level of household head: 1= Illiterate. 2= Read and Write (1-4). 3=Elementary school (5-8). 4= High school (9-12)
2.5. Marital status: 1= Married. 2= Single. 3= Divorced
2.6. Household size

No.	Age	Number		
		Male	Female	total
1	Less than 15 years			
2	15-65 years			
3	Above 65 years			

3. Socio-economic Characteristics of HHs

3.1. What is your source of income?
1= Only Agriculture, 2= Agriculture and off-farm, 3= Agriculture and Non- farm
4= Agriculture, off farm and non-farm
3.2. Farming system you follow currently
1= Crop production only 2= Livestock rearing only 3= Mixed farming 4= others (please specify)...
3.3. Do you/any members of your family has any sources of non-farm income i.e. income from remittance, petty trade, employment in government or private enterprise, etc.?
1= Yes 0= No
3.4. If yes to the above question, how much money you/your family make per year on average from off-farm activity? Please specify in Birr: ....
3.5. Total farm land, including any grazing land (including rented land and excluding rented out land) ____________(in temad)___________
3.6. Size of land rented in (temad)____________ Size of land rented out(temad)____________
3.7. Do you have tenure security certificate for your land? 1= Yes 0= No
3.8. What are the physical characteristics of your farm, in terms of its exposure to erosion?
1= Susceptible to erosion 2= moderately susceptible to erosion 3= Not susceptible at all
3.9. How was the fertility of the soil of your farm in general?
1= Very fertile .... 2= Moderate................. 3= Poor/ infertile
3.10. Dear respondent! How many of the following types of livestock do you have?
Please fill in the head count column.

Sn.	type	Head count	type	Head count
1	cow		Mule	

2	Calf		Goats	
3	Oxen		Sheep	
4	Horses		Poultry	
5	Donkey		other	

4. Objective 1:- Climate Change Related Information and inventory of Climate Smart Agricultural practices implemented

4.1. Would you say that there have been severe changes in climate in the last 20 years?
1=Yes 0=No

4.2. Comparing the 1999s with the recent past 20years i.e. 2019, have you perceive any changes in climate? 1= Yes 0= No

4.3. Comparing the 1999s with the recent past 20 years i.e. 2019, have you noticed any changes in the rainfall patterns? 1= Yes 0 = No

4.4. If yes, please specify the pattern of the change in rainfall you have noticed.
1= Increasing 0= Decreasing

4.5. Comparing the 1999s with the recent past 20 years i.e. 2019, have you noticed any changes in temperature? 1= Yes 0 = No

4.6. Have you ever faced any climate related hazard related to rainfall variability in your locality which altered your production? 1 = Yes. 0 = No.

4.7. If yes, what type of climate related hazard? 1. Excess Rainfall. 2. Drought. 3. Erratic Rainfall. 4. Others, specify--

4.8. When did you observe? 1= Keremet season. 2= Crop harvesting season 3= Bega season

4.9. If the answer to Q4.6. is yes, did it affect your crop production? 1 = Yes. 0 = No.

4.10. If yes to what extent? 1= Full crop damage. 2= Partial crop damage. 3= Increased Crop disease and weeds. 4= others, specify……………………..

4.11. Has crop diversity increased between climate variability? 1 = Yes. 0 = No

4.12. What were the agricultural indigenous skills you have taken during climate related hazard had been occurred? Any traditional prediction system if you have?

4.13. What are the major constraints that hinders your coping mechanisms?
1= Lack of climate information. 2= Lack of access to climate information.
3= Lack of technology. 4= Lack of money. 5= others, specify -----------------------------

4.14. Have you made any changes in your farming practices following the bad incidences?
1=Yes 0= No

4.15. Do you know about CSA technology? Enumerator, refer to your note on CSA approach and practices. 1= Yes 0= No

4.16. What do you know about CSA practices? Explain ……………………………………………………………………………………………When do you start to use this climate change adaptation practice? (time of years)--

4.17. Which of the implemented activities are more effective with respect to production? --

4.18. Why did you implement the above CSA practices?
- To reduce runoff = 1 - To harvest water = 2 - Increase crop yield = 3
- Other (specify) …………. ……………………………. ……………………………..

4.19. Which kinds of CSA practices do you currently have at your plot(s)? *Tick all that apply.* 1=Use of improved crop varieties 2=Use of legumes in crop rotations 3= Use of cover crops

4=Changing planting dates 5=Diversification of livestock breeds and crop varieties 6=Organic fertilization (use of compost, animal and green manure 7=Efficient use of nitrogen fertilizer 8= Use of terraces, contour farming 9=Irrigation 10=Reduced/ minimum/zero tillage 11=Trees on cropland(agroforestry) 12=Mulching 13=Use of improved livestock breeds 17=Others (specify)---

4.20. Assuming you had the option of practicing a combination of any of the following CSA techniques, which combination do you think will give you the highest yield for your crops? List in order of priority.

Crop type   CSA combination

____________   __________________________________

____________   __________________________________

Enumerator, enter crop code/type from your notes

4.21. Please give reason(s) for your answer in Q 4.21? ____

4.22. Please would you rank the effectiveness of different climate smart practices that are implemented in the area?

4.22.1. In conserving environment--- Productivity increment and sustainability ---

4.22.2. Social acceptance--

4.23. What are the challenges involved in adoption of the above strategies?

1 =Lack of capital 2 = Lack of information 3=Shortage of labor 4=Lack of access to water 5=others (specify)

5. Objective 2:- effectiveness of CSA practices implemented

5.1. Do you apply climate smart agricultural practices on your farm fields?1= yes 0= No

5.2. If yes, when did you start using the practices? _____________________ (time of year)

5.3. Can you mention the types of climate smart crop production practices you are using? _____________________,______________________,_________________________

5.4. In which crop the technologies were introduced?

1. ________________2.________________3.__________________4. _____________

5.5. Indicate the type of technology used during the project, continue to use and source of information.____ Will you continue using CA technologies in the future? 1= Yes 0= No

5.6. What proportion of your farm practice CA technologies introduced?

1= Quarter 2= Half 3=Three quarter 4=All

5.7. Having applied these interventions, have you observed a change in yield production of crops after the start of the intervention? *1= Yes 0= No*

5.8. If your answer is yes, how is the trend of the crop production? 1= Increasing 2=Decreasing

5.9. Do you use improved crop seed varieties? If yes, mention the type of crop varieties you use? ____

5.10. How do you see the futures of climate smart crop production practices in your locality in relation to adapting climatic problems? 1= Advisable 2= Not advisable 3= It is difficult to judge 4= I have no idea 5= Others specify__________________________

5.11. What would you benefit in future from these CSA interventions?(looking from sustainability perspectives) ____

5.12. What was your total yield (in 50 kg bags) in 2016, 2017 and 2018 production years?

Type of crop	2016/17		2017/18		2018/19		total	
	Yield	Price (Br)	Yield	Price (Br)	Yield	Price (Br)	Yield	Price (Br)

5.13. In the past five years (2016 – 2018) did you experience any change in yield?

- 2016 - 2017 - 2018

In 50kg bags Yes = 1 (amount) No = 0

5.14. What do you think was most responsible factor for your experience?

- Availability of ground water due to reduced run-off ----Yes = 1 No = 0
- Increased percolation of rainwater --------------------------Yes = 1 No = 0
- Better manure on soil surface--------------------------------- Yes = 1 No = 0
- Other (specify)

5.15. What was the amount of expenses for the production of crops in the three years?

Type of inputs used	2016/17		2017/18		2018/19		total	
	amount	Price (Br)	amount	Price (Br)	amount	Price (Br)	amount	Price (Br)
Fertilizer & chemicals								
Improved seeds								

5.16. Income from sell of CSA livestock in the table below:

	Type of livestock								year
	Ox	Cow	Bull	Sheep	Goat	Calf	Hen	others	
Livestock number									
Livestock sold									
Unit price									
Total sale price									
Purpose									

5.17. Income from sale of livestock products and by products during in 3 production years?

Type of products and by products	Quantity Unit	Amount collected	Amount consumed in a year	Sold in a year(birr)	Year sold
Milk					
Butter					
Egg					
Honey					
Total income					

Objective 3: challenges for the adoption of CSA practices

5.1. Why do you want to continue/not to continue using these technologies?

____

____

5.2. Are there any constraints that may make you not to continue using CSA technologies? 1= Yes 0= No

5.3. What are the constraints/challenges encountered during the implementation of CSA introduced technologies?

Institutional Factors

Extension Services

5.4. Did you get advisory service from extension service during the production year? 1. = Yes. 0 = No

5.5. Was the extension service given related to climate change and adaptation strategies/CSA practices? 1=yes 0= No

5.6. Has any household member receive extension service in the last 12 months?
1= Yes 0 = No

5.7. If yes (for 5.5), If yes, how frequencies do the extension agents' visit you? 1=Once a week. 2= every 15 days. 3=Monthly. 4=weekly

5.8. What are the supports given to you? 1= Advice. 2= Training. 3= Demonstration.
4= Conflict resolution. 5= Controlling water distribution. 6=Others specify……

5.9. On what topics you get support from extension service?

………………………….. , ………………………….. , ………………………….. , Have you got extension service in the following Climate smart agricultural practices? Put (√) in the box provided.

Type of CSA practices	yes	No	Type of CSA practices	yes	No
Composting/organic fertilizers			Agroforestry		
Residual management			SWC Practices		
Mulching			other		

Credit services

5.10. Have you ever used credit for your agricultural activities in the last three production years? 1 = Yes. 0 = No

5.11. If yes 5.10, for what purposes do you obtained credit? 1= Purchase of improved seed 2= Purchase of fertilizer 3= Purchase of farm equipment 4= To fill up family requirement 5= Livestock purchase 6= Petty trade 7= Others (specify)

5.12. what is the source of the credit?

5.13. If you did not use credits, what is your reason? 1 = lack of asset for collateral, 2 = no one to give credit, 3 = high interest rate, 4 = no need credit, 5 = others

5.14. Do you save money? 1 = Yes. 0 = No

5.15. If yes, in what form do you save? 1= Iqub. 2= in the form of livestock 3= Save in bank. 4= Others---

Appendix 2: Key Informant Interview questions

Name____

Position/profession____

1. Would you like to explain the different climate problems which are frequently happen in your region?
2. what are the effects of climate change on the livelihood of farmers in your area?
3. What do you suggest to be done to reduce the impacts of climate change in yours district?
4. Does the farmer use any climate smart agricultural practices to response climate related problems? 1=Yes 0=No
5. If yes Q. 4 what types of climate smart agricultural practices used please mention the most common climate smart agricultural practices practiced in this district?

6. What is the effect of using these CSA practices on farmer's yield of agricultural production?
7. Does CSA reduce the cost of production?
8. How much your yield Increase due to CSA (percent)?
9. Does the community have enough information about CSA?
10. How do you observe the CSA practices from environmental friendly and sustainability perspectives?
11. What are the challenges/factors to farmers to use or scale up these practices?

Appendix 3: Check list to guiding Focused group discussion

1. The major farming activities undertaken in the area.
2. The major sources of income to support life in the district.
3. Is there climate variability and climate change in the area in the last 20 years?
4. What are Climatic change related shocks in the area.
5. Have your area affected by climate change over the time?
6. Does climate change have negative impact on agriculture?
7. What are the Major climate smart agricultural practices implemented in the local area?
8. What are the roles of these practices to response to climate change? (with respect to adaptation and mitigation)
9. How do you see the effect of CSA on yield of crops?
10. What about the cost of production with respect to conventional agriculture
11. .List the Determinants for farmers' choice to adopt climate smart agricultural practices.

Appendix 4: Livestock conversion factor

Livestock	Conversion factor
Oxen	1.1
Cow	1.0
Heifer	0.5
Calf	0.2
Sheep	0.1
Goat	0.1
Donkey	0.5
Mule	0.7
Hen	0.01

Source: (Land O'Lakes International Development, 2007).

Appendix 5: Variance Inflation Factor (VIF) of continuous explanatory variables

Variables	Tolerance	VIF
age of household head	.926	1.079
family household size	.616	1.622
Dependency ratio	.606	1.651
total tropical livestock unit	.843	1.186
land holding size in ha	.866	1.154
Off farm income	.896	1.117

a. Dependent Variable: adoption of CSA practices

NB:-Rule of thumb collinearity exist when VIF value greater than 5. If there is no colliniarity between variables the VIF should be 1. In other case when the tolerance value is greater than 0.2, then there is less/no collinearity between the variables.

$$\mathrm{VIF} = \frac{1}{(1 - Ri2)}$$

Appendix 6: Contingency coefficient test of categorical explanatory variables

explanatory variables	sexHH	edulevel	FrqncyEx	demo	training	crditusd
sexHH	1					
edulevel	0.127784	1				
FrqncyEx	0.047377	0.341727	1			
demo	0.055357	0.221979	0.260435	1		
training	0.131322	0.232703	0.205604	0.075709	1	
crditusd	-0.07195	0.317235	0.170635	0.182142	0.047474	1

No collinearity problems since contingency coefficient test value is less than 0.8 for those dummy variables,

Biographical Sketch

The author was born to his father Limenih Yizenegaw and his mother Yayeshe Birehanie in East Gojjam zone of Amhara Regional state, Ethiopia, on Dec.24, 1984. He attended his Elementary education at Genetu primary school, Secondary and preparatory education at Alemayehu Bezabeh Secondary School and Feres Bet senior secondary School respectively. He joined Wondo Genet College of Forestry in 2003 and then Bahir Dar University in Jully 2008 and successfully completed his Diploma and Bachelor of Science degree study in forestry and Rural development respectively. Immediately after graduation, the author was employed in Bibugn district and work as forest development and soil and water conservation expert for more than 8 years. After June 2015 to then, he is an expert in Ministry of Agriculture in extension department and now after JEG in CRGE directorate.

In September 2018, he joined Hawassa University to pursue his post-graduate study in the department of Climate Smart Agricultural Land scape Assessment.