COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR ENVIRONMENT AND DEVELOPMENT

FACTORS INFLUENCING FARMERS' ADOPTION AND PROFITABILITY OF CLIMATE-SMART AGRICULTURAL TECHNOLOGIES AMONG RICE FARMING HOUSEHOLD: A CASE STUDY OF FOGERA WOREDA OF AMHARA REGION, ETHIOPIA

BY

BELACHEW GETNET SENDEK

A THESIS SUBMITTED TO THE CENTER FOR ENVIRONMENT AND SUSTAINABLE DEVELOPMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ART (ENVIRONMENT AND SUSTAINABLE DEVELOPMENT)

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This is to certify that the thesis prepared by Belachew Getnet Sendek, entitled: *Factors Influencing Farmers' Adoption and Profitability of Climate-Smart Agricultural Technologies Among Rice Farming Household: A Case Study of Fogera Woreda of Amhara Region, Ethiopia,* and submitted in partial fulfillment of the requirements for the degree of masters of art (environment and sustainable development) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Internal Examiner ___________________Signature _____________ Date_____________

External Examiner ____________________Signature _____________Date _____________

Advisor: Dr. Aseffa Seyoum Signature _____________Date_____________

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Chair of Department or Graduate Program Coordinate

DECLARATION

I, the undersigned, declare that this thesis entitled '*Factors Influencing Farmers' adoption and Profitability of Climate-Smart Agricultural Technologies Among Rice Farming Household: A Case Study of Fogera Woreda of Amhara Region, Ethiopia'* is my original work and has never been presented in any university. All the sources and materials used for the thesis have been properly acknowledged.

Name: Belachew Getnet Sendek

Signature:____________________

ID: GSE/3266/12

Date:_________________

Place: Addis Ababa University

This thesis has been submitted for examination with my approval as University advisor.

Name: Dr. Aseffa Seyoum

Signature: ____________

Date: ___________

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ACRONYMS AND ABBREVIATIONS

CRGE	Climate Resilient Green Economy
CSA	Climate Smart Agriculture
ESS	Ethiopian statistical service
FAO	Food And Agricultural Organization
FDRE	Federal Democratic Republic Of Ethiopia
GM	Gross margin
GFR	Gross farm income/revenue
GIS	Geographical Information System
GPS	Global Positioning System
IPCC	Intergovernmental Panel On Climate Change
IPMS	Improving Productivity And Market Success
MOA	Ministry of Agriculture
MoARD	Ministry of Agriculture And Rural Development
OECD	Organization for Economic Co-operation and Development
SNNP	Southern Nations, Nationalities, and Peoples
SPSS	Statistical Package for the Social Sciences
TLU	Tropical Livestock Unit
TVC	Total Variable Cost of Rice Production
TFC	Total Fixed Cost of Rice Production
TPC	Total Rice Production Cost
VIF	Variance Inflation Factor

ABSTRACT

Rice is a nutritional staple food grown under flooded and submerged conditions introduced in Ethiopia to ensure food security. Because of unfavorable climate conditions, agricultural productivity and profitability are threatened. So, CSA technology has been introduced to address those challenges. This study tried to assess factors influencing farmers' adoption and profitability of CSA technologies among rice farming households of Fogera Woreda, Amhara Region. A cross-sectional study design was employed with both qualitative and quantitative data collection approaches. Household survey data were collected from randomly selected 376 farmers in 5 purposively selected kebeles while the qualitative data were collected by interviews with key informants. Out of 376 respondents, 36.2% of them maintain crop residue while 63.8% of them did not. Regarding compost, 37.8% of the total respondent was adopter whereas 62.2% did not. Likewise, 55.1% of the total respondent constructed soil bunds but the remaining 44.9% did not. The profitability of climate-smart rice production was estimated by net profit and gross margin analysis. The result revealed that CSA technology adopters earned more gross margin and net profit than non-adopter. Factors influencing smallholder rice farmers' adoption of CSA technologies were analyzed by the binary logistic regression model. The result showed that sex, age, road distance, family size, number of livestock owned, farm income, access to extension services, access to a mobile phone, and education significantly influence farmers' decision to adopt CSA technologies. Thus, the result of this study recommends that broadening awareness via accessing communication technologies, strengthening extension service based on identified skill gaps, improving infrastructural accessibility, and improving economic conditions of rice farmers by government and other stakeholders enhances the adoption of CSA technology.

Key Words: *Climate-smart agriculture, Profitability, Farmer's adoption, Rice, Household, Fogera*

CHAPTER ONE

INTRODUCTION

1.1. Background

Rice (Oryza sativa L.) which belongs to the family of Poaceae is a semi-aquatic cereal crop grown within the stagnant waters of wide areas of the plain and the tropical soils found near the sea level (MoARD, 2010; Anteneh, Ayele, & Adane, 2021). However, according to Anteneh, Ayele, & Adane (2021), there are few upland rice varieties. It is a universal food that plays a critical role to address the challenges of food insecurity (MoARD, 2010).

Rice is the oldest cereal crop of Southeast Asia recently cultivated extensively in various areas of Asia, America, and Africa. Rice has heat-loving characteristics and often grows well from sea level up to three thousand meters like in the Himalayas (MoARD, 2010). Asia and the Pacific region mostly south and east Asian nations cultivate and utilize around 90.6% of the planet's total rice crop. China is the leading nation in the world in rice growing by means of area coverage and production. The amount of paddy yield produced by China was 214,403,870.05 tonnes during the year 2021. On the opposite hand, Africa accounts for 3.7% of the worldwide rice crop production in the year 2021. Rice has been gradually becoming the main source of food in Africa with 37,188,988.64 tonnes of grain yield production on the 15,828,504 ha area of land in 2021 (FAOSTAT, 2022). According to FAO regional office for Africa, (2022) continental rice production meets only two-thirds of annual consumption demand. As seen by the report of MoARD (2010), Africa has a huge capacity for rice production since it grew around seventy-five percent of the continent's nations, which have an estimated population of eight hundred million.

Nowadays, rice is alongside other prominent cereal crops cultivated in various areas of Ethiopia as a food crop. Ethiopia has massive potential for rice crop farming which lies in the western part of the nation. According to Tadesse (2020), around 39,354,190 hectares of land are predicted to be favorable for paddy cultivation in Ethiopia. Whereas, 85,288.87ha area of land was cultivated for rice production during the year 2021. The amount of cultivated rice paddy fields in Ethiopia is low as compared to its potential which covers 0.2% of the total potential area. However, the Amhara regional state takes the lion’s share of rice production with 57.9% of the area coverage and 62.97% of the production during the year 2021 (Central Statistical Agency, 2021a).

Fogera Plains are one of the key rice production areas that have demonstrated massive agrarian changes associated with rice introduction and commercialization (Alemu, 2019). According to Alemu (2019), Ethiopian domestic paddy yield enhanced from 71,316 tonnes in 2008 to 126,806 tonnes in 2016. Furthermore, Ethiopian national rice production in the year 2021 was 200,000 tonnes (FAOSTAT, 2022).

Recently, farming has become a very complex business due to climate change and unpredictability which is threatening agricultural productivity including rice production. Ethiopian economy also relies on subsistence farming like crop production and their productivity is threatened by climate change and variability. Farmers adopt climate-smart agricultural technologies to boost their agricultural yield and profitability along with safeguarding the environment. The study result of Sardar, Kiani & Yasemin (2020) reveals that farmers who adopted climate-smart agricultural technologies attained sufficient yields and farm earnings. In addition, the use of improved seeds, reduced/zero tillage, and laser land leveling as climate-smart agricultural practices increased crop yields in smallholder farmers (Arun et al., 2016). The government of Ethiopia also adopts the CRGE strategy to build climate-resilient economic growth by reducing the influence of climate change (FDRE, 2011).

Inmaculada et al. (2015) in their study conducted in southern Spain argue that farmers' socioeconomic conditions such as availability of land, financial capital or resource, individual behaviors, and socio-cultural background can influence the adoption of conservation agriculture systems. Likewise, Nguyen & Chinawat (2015) find out that sustainable agriculture perception, education, economic condition, extension course, and feasibility of practice influence farmers' adoption of sustainable cultivation practices within the Vietnam uplands of Quang Tri province. So, to enhance rice profitability and productivity, it is vital to implement CSA technologies effectively by uncovering adoption determinants.

1.2. Statement of Problem

Rice is considered "the Millennium Crop" and introduced in recent times to assure food security in Ethiopia. Rice is the essential crop cultivated in various parts of Ethiopia since there is immense potential in the western part of the country (MoARD, 2010). Fogera Woreda takes the lion's share in terms of paddy rice production and area coverage in Ethiopia as well as in Amhara. However, the amount of yield in rice production shows improvement while it did not record any raise in productivity (Abebaw, 2019). Climate change is a widely growing threat to cultivation, food security, and the livelihood of lots of people living in various areas around the globe (IPCC, 2014).

According to MoARD (2010), Ethiopian agricultural farming remains mainly rain-fed, with limited market orientation, supported by undeveloped technologies and environmentally unsafe practices. Rapid population growth along with increasing demands for more farmland (Zegeye & Fikire, 2021) exacerbates the degradation of the environment and natural resources that threatens the agricultural productivity of Ethiopia at large as well as the Amraha region including Fogera woreda.

So, Low agricultural yields are related to unfavorable climate conditions. Climate-smart agricultural practices have been introduced to improve agricultural productivity generally and rice productivity specifically through safeguarding the environment. According to FAO (2018), climate-smart agriculture is a practice of transforming agricultural systems towards green and climate resilient. So, agricultural yield and profitability can be enhanced by means of effectively implementing climate-smart agricultural practices (Donkoh, Azumah, & Awuni, 2019; Victor, Melusi, & Ajuruchukwu, 2019; Khoi, et al., 2021). The adoption of climate-smart agricultural technologies at the farmer's level for rice production is still less explored.

Farmers' exposure to climate change is increasing from time to time whereas their commitments to transform their farming practices aren't visible. So, they might be technically not prepared or hesitant to adopt technologies, or they might not be able to recognize the long-term returns of changing farming practices. Smallholder farmer often lacks knowledge of existing and new potential options to become accustomed to climate changes for their agricultural productivity (Njuguna, 2020).

Few studies were conducted to identify factors influencing farmers' adoption of climate-smart agricultural technologies in rice farming. Etim & Ndaeyo (2020) discovered that education status, number of family members, farm revenue, and access to information on climate change were determinants of rice farmers' willingness to adopt climate-smart agricultural technologies in the Akwa-Ibom state of Nigeria. Dung (2020) investigate determinants of climate-smart agricultural technology adoption among rice farmers in Vietnam and found that educational status, area of paddy field, access to credit, social assets, access to extension, secured farmland tenure, perception of rice farmers on climate change impact, and access to the market influence climate-smart agricultural technology adoption. Tran et al. (2019) studied the factors influencing the adoption of climate-smart agricultural technologies by rice farmers in Vietnam. Their study output shows that sex, age, number of family workers, climate-related aspects, the paddy field characteristics, distance to markets, access to climate data, trust in extension workers' expertise, membership in social or agricultural groups, and perception toward hazard were critical factors influencing climate-smart agricultural technologies adoption among the rice farmers.

However, the influence of access to communication technologies like a mobile phone on the adoption of climate-smart agricultural technologies in rice farming is not well studied. Beyond and above, the profitability of rice farming through adopting CSA technologies is also not well-known and not well-addressed in various research outputs. In addition to the above, none of the above studies have been conducted in Ethiopia as well as in Fogera wereda. Therefore, this research is conducted to contribute knowledge to the endeavor by assessing the practice, investigating factors influencing farmers' adoption, and estimating the profitability of climate-smart agricultural technologies among smallholder rice farming households.

1.3. Research Questions

- ✓ What is the practice of climate-smart agriculture among smallholder rice farmers of Fogera Woreda?
- ✓ How much climate-smart agricultural technologies adopted by smallholder rice farming households are profitable?
- ✓ What are the factors influencing smallholder farmers' adoption of climate-smart agricultural technologies in the rice farming household?

1.4. Objectives

1.4.1. General Objective

To assess factors influencing farmers' adoption and profitability of climate-smart agricultural technologies among smallholder rice farming household in Fogera Woreda of Amhara Region.

1.4.2. Specific Objective

- To assess the practice of climate-smart agriculture among smallholder rice farming household.
- To estimate the profitability of climate-smart agriculture among smallholder rice farming household.
- To investigate factors influencing farmers' adoption of climate-smart agricultural technologies in the smallholder rice farming household.

1.5. Significance of the Study

Nowadays, climate change is threatening agricultural productivity and profitability in general and rice production in particular. Rice farming household increases their production as well as income and also improves their adaptive capacity by introducing climate-smart agricultural technologies. The finding of this research will give valuable evidence for policymakers to formulate development program strategies on CSA technology adoption. It will also provide information on CSA technologies in rice farming for rice producers. It will use as an insight for researchers and academicians for further research.

1.6. Limitations of the Study

The researcher encountered a few limiting factors during the study of factors influencing farmers' adoption and profitability of climate-smart agricultural technologies in smallholder rice farming households. Those hindering factors were time, finance, and transportation access to arrive at the selected kebele. Furthermore, a few respondents were reluctant to offer their reply by the reason of wanting an incentive for their response.

1.6.1. Time Constraints

In this study, the shortage of time for gathering valuable research data from smallholder rice farming households in sampled Kebeles of Fogera woreda was one of the constraints to investigating factors influencing farmers' adoption and profitability of climate-smart agricultural technologies. Lastly, the researcher makes the study achievable.

1.6.2. Financial Constraints

Finance was another limiting factor when conducting this research. Because, the expense of transport, per diem for data collectors and material purchasing requires monetary resources. The expense of this study was covered by the researcher's finance alone without getting any grant or financial resources. As a result, the shortage of finance was another challenge to accomplish this study.

1.6.3. Transportation Constraints

Another limiting factor encountered in the field during the data gathering process was the accessibility of selected rural rice cultivator Kebeles of Fogera wereda for transportation.

1.7. Scope of the Study

The scope of this study was delimited by geographic area, unit of observation, time, and thematic issues.

1.7.1. Delimitation by Themes

The study relied on assessing factors influencing farmers' adoption and profitability of climate-smart agricultural technologies namely maintaining crop residue, use of organic manure or compost, and water management through constructing soil bunds in rice farming households. Other climate-smart agricultural technologies or practices that enhance rice crop productivity/profitability and also preserve the environment were out of the domain.

In short, the central element of this research was; assessing the practice of CSA, estimating the profitability of adopted climate-smart agricultural technologies, and investigating factors influencing farmers' adoption of climate-smart agricultural technologies in smallholder rice farming households.

1.7.2. Delimitation by Geographic Area

The scope of this study was also delimited by the Geographic area which typically lies in Fogera Woreda of Amhara region, North West Ethiopia. As a result, this study targeted Shina, Shaga, Kidest Hana, Abagunda Sendega, and Dilmo Kebeles of Fogera Woreda which was selected purposively.

1.7.3. Delimitation by Unit of Observation

In addition, the scope of this study was also delimited by target groups. The target groups included in this study and served as a source of primary data were sampled rice farming household respondents and key informants (woreda and kebele agricultural experts).

1.8. Organization of the Thesis

On the basis of the study objectives, this study has been divided into five chapters. The background of the study, the problem statement, the objectives, the research questions, the significance, the limitations, the scope, and the organization of the study is introduced in the first chapter. Chapter Two reviews the conceptual, theoretical, and empirical literature on factors influencing farmers' adoption and profitability of climate-smart agricultural technologies in smallholder rice farming households. Chapter Three also addressed the study's design and methodological approach. The findings and results of the study are presented and discussed in chapter four. The conclusion and suggestions of the main findings are shown in chapter five of the paper.

CHAPTER TWO

LITERATURE REVIEW

2.1. Rice Production Trend in Ethiopia

Rice is the most important food grain which is a member of the Poaceae (old Gramineae) botanical family and placed in the Oryzeae tribe (Dilnesaw et al., 2019). Rice was introduced in Ethiopia during the Derg regime to address the issue of food security. So, it was introduced for the first time in the Gambella, Pawe, and Fogera areas of Ethiopia (Alemu et al., 2018). According to Dessie (2020), rice is introduced into Ethiopia in the 1970s. Ethiopian rice production trend increases from 11 thousand tons within 6421ha of paddy field during 2006 to 184 thousand tons within 58806ha area of paddy field during 2013 (Alemu, 2015). Whereas, Ethiopian national rice production in the year 2021 was 200,000 tonnes (FAOSTAT, 2022).

Therefore, the government of Ethiopia recognizes rice as a millennium crop projected to make a difference in assuring food security. Paddy rice is cultivated in Amhara, Tigray, Oromia, SNNP, Gambella, and Benshangul Gumuz regions of Ethiopia. The potential areas suitable for rain-fed rice crop growing in Ethiopia is estimated to be about 39,354,190 hectares which lie within the western part of the country. In addition, the potential area for irrigated rice crop growing is estimated to be about 3,798,782 hectares (Tadesse, 2020). It was assessed through GIS techniques using rainfall, slope, soil texture, altitude, and temperature parameters (MoARD, 2010). Beyond and above, 85,288.87ha area of land was cultivated for rice production in Ethiopia during the year 2021. The amount of cultivated national rice paddy fields is low as compared to its potential which covers 0.2% of the total potential area (Central Statistical Agency, 2021a).

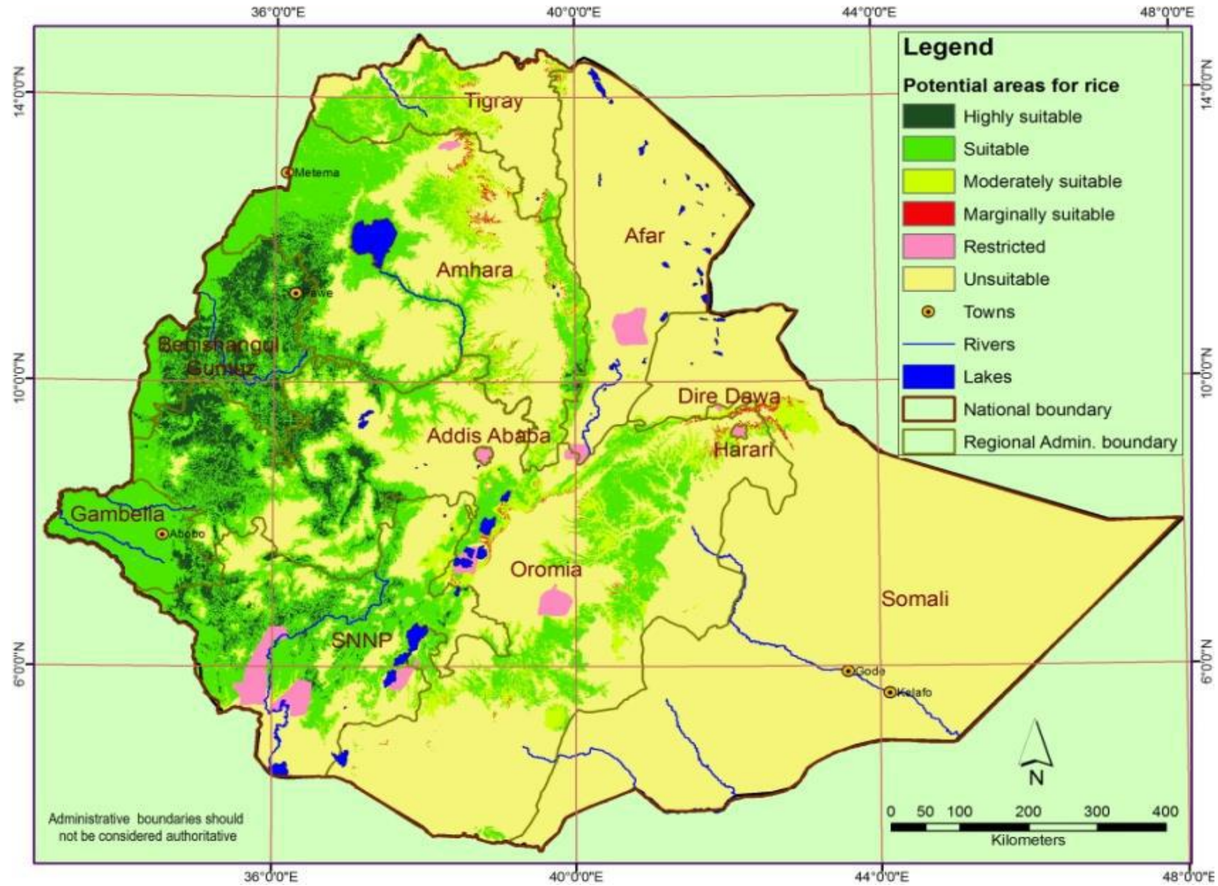

Figure 1: Map of potential areas suitable for rice crop growing in Ethiopia (MoARD, 2010)

The Ethiopian national rice research strategy recognizes about seven rice research and development hubs or major rice growing areas (Alemu, 2019; Alemu & Thompson, 2020; Alemu & Assaye, 2021). These are:

1. **Fogera Hub** covers the west-central highlands of the Amhara Region mainly Fogera, Gonder Zuria, Dembia, Takusa, Achefer, and Metema Districts.
2. **Pawi Hub** covers northwest lowland areas of Amhara and Benshangul Gumuz Regions mainly Jawi, Pawe, and Dangur Districts.
3. **Abobo Hub** covers the Abobo and Etang Districts of Gambella regional state.
4. **Gura Fereda Hub** covers the south and southwest Lowlands of southern nations' nationalities and peoples' regional states mainly Beralee, Weyito, Omorate, Gura Ferda, and Menit Districts.

5. **May Tsebri Hub** covers the Northwest part of Ethiopia;
6. **Gode Hub** covers the Southern part of the Somali Region primarily engaged in irrigated rice.
7. **Chewaka Hub** covers the Southwestern highlands of the Oromia Region mainly Illuababora, East and West Wellega, and Jimma Zones.

2.2. Rice Production in Fogera Woreda

Fogera plain is one of the core paddy production areas in Ethiopia that has demonstrated huge agrarian changes associated with rice introduction and commercialization (Alemu, 2019). Based on IPMS (2005) rice crop was introduced to the Fogera Woreda during 1987 E.C. with 30 farmers in two farmers' associations on 6 hectares of land. The average crop yield in rice production was 20 quintals per hectare. As shown in the study finding by Hagos & Zemedu (2015), the Fogera district generates almost 58 percent of the Amhara and 28 percent of the nation's rice yield. Rice is the main crop cultivated and produced in the area.

The area of Fogera plain is waterlogged during the main rainy period which was unsuitable for crop production other than rice. Traditional crops cannot grow in such conditions. Before the introduction of rice, smallholder farmer at the Fogera plain only grew some crops after the water receded with residual moisture, and also they were engaged in livestock production (Tadesse, Assaye, & Alemu, 2018). Since the introduction of rice in the area, the farmers' lives have tremendously transformed from livestock production to rice production. Accordingly, the rice crop plays a significant role to change the livelihood of farmers through relaxing the problem of food insecurity at Fogera plain (Takele, 2010).

2.3. Climate-Smart Agriculture

Climate-smart agriculture is defined as "an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change" (Lipper, et al., 2014, p. 1068). According to FAO (2018), the idea of climate-smart agriculture was established in 2010 by FAO are farming that sustainably boosts agricultural income and profitability, improves the resilience of livelihoods and ecological systems, minimizes and/or eradicates greenhouse gases emissions, and improves the realization of countries food security and development targets. So, climate-smart Agriculture combines three principles of sustainable development i.e. economy, society, and environment by mutually tackling the problems of food security and climate change (Nciizah & Wakindiki, 2015; FAO, 2018). For example, minimum or zero tillage can minimize carbon losses from plowing and increasing the organic content of the soil which contributes to making yields more resilient, mitigating climate change, and reducing soil erosion.

Climate-smart Agriculture is not a prescribed practice or a particular agricultural technology or practice which can be adopted across the world. Climate-smart agriculture aims to achieve all three pillar objectives but it doesn't mean that almost any agricultural practice adopted in each area necessarily achieves all three pillar objectives. It is a site-specific program that demands site-specific analysis of the social, economic, and environmental situations to determine the most suitable agricultural production technologies and practices (FAO, 2018; Lipper, et al., 2014). So, it is an approach that helps farmers to increase their productivity and income or profitability sustainably.

The three main principles of CSA are productivity, adaptation, and mitigation (FAO, 2013). Those are:

Productivity is the first pillar of climate-smart agriculture which aims to enhance agricultural productivity and incomes without harming the environment. productivity raises through sustainable intensification to elevate food security (Totin, et al., 2018).

Adaptation is the second pillar that seeks to make farmers less susceptible by altering the exposure, reducing sensitivity, and increasing adaptive capacity (FAO, 2013).

The third pillar of climate-smart agriculture is **mitigation** which promotes activities to reduce minimize and/or eradicate greenhouse gas emissions (FAO, 2013).

2.4. The Review of Theoretical Literatures

2.4.1. Technology Acceptance Model

This theory was proposed by Davis (1989) to explain users' acceptance of technologies or information such as climate-smart agricultural technologies. The attitude of users toward technologies was the main factor to use or reject the system. So, the attitude to use is the users' estimation of the attractiveness of certain technology for adoption. Behavioral intention is the determining of the probability of an individual choosing the technologies like CSA. Based on this theory perceived usefulness and perceived ease of use are preconditions for technology as well as information acceptance that is influenced by social, political, and cultural factors (Davis, 1989). According to Davis (1989), perceived usefulness is the extent to which users believe/recognizes that using certain technology such as CSA would improve his/her performance. For example, rice farmers' expectation about how CSA technologies boost their productivity influences their CSA technologies acceptance. Whereas, perceived ease of use also measures the extent to which users believe/recognize that using certain technology such as CSA would be effortless.

This theory was used in this study to investigate factors influencing smallholder rice farmers' decision to adopt CSA technologies. As a result, this theory was applied to know smallholder rice farmers' perception regarding unpredictable climate change and the usefulness of CSA technologies influence their decision to choose or not for adoption.

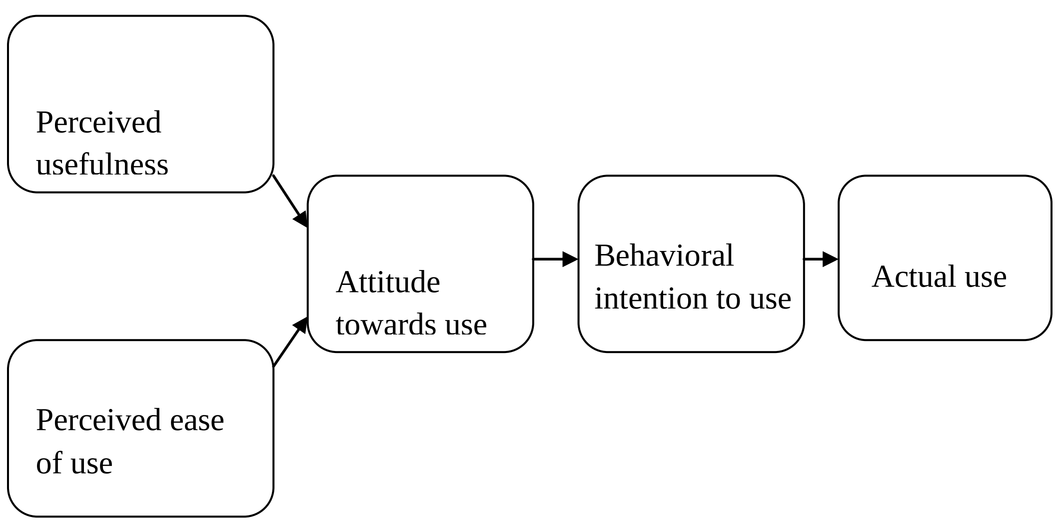

Figure 2:The model of technology acceptance adopted from Davis (1989)

2.4.2. The Theory of Utility Maximization

Farmers choose agricultural technologies for adoption if and only if it maximizes their utilities as well as profit from the previous one (Udemezue & Agwu, 2018; Foster & Rosenzweig, 2003). However, the aim of farmers is not only profit maximization rather it includes attaining minimum subsistence necessities, maintaining social status, and others. As a result, farmers decide to adopt agricultural technologies such as CSA which can be single or combined (Njane, 2007). On the other side, their decision on adopting climate-smart agricultural technologies is determined by risks and uncertainties (Mendola, 2007). Their decision to adopt climate-smart agricultural technologies is influenced by the social, demographic, and economic characteristics of farmers (Njane, 2007) as well as agro-ecological, institutional factors, and individual likings regarding the properties of a particular technology (Adesina & Baidu-Forson, 1995).

This theory was used in this study to assess factors influencing farmers' adoption and profitability of CSA technologies in the smallholder rice farming household of Fogera Woreda. As a result, this theory assumed that maximum profit can be achieved along with safeguarding the environment by adopting CSA technologies in the paddy field of a rice farmer.

2.4.3. The Theory of Innovation Diffusion

Individuals choose technologies like CSA to adopt or reject through analyzing the cost and benefits (Rogers, 1983; Orr, 2003). People adopt technology if they think that this technology would boost their profits/utility (Orr, 2003). The theory of innovation diffusion by Everett Rogers describes how, why, and at what speed innovations disseminate through time in social systems. This theory also explains the adoption determinants of innovations such as climate-smart agricultural technologies. As shown in the books by Rogers the core components of the diffusion of technologies were innovation or technology, communication channels, time, and a social system (Rogers, 1983).

Innovation, in Rogers' meaning, is an idea, practice, or product like CSA technologies that are recognized as new by user persons or organizations. If individuals believe that it's new regardless of whether something has been invented years ago, it might just be counted as an invention. The next component of the diffusion of technologies, the communication channel is the spread/transfer of the knowledge of innovation among people or organizations. Time, the third component is the length of time required for the diffusion of technologies. It is the relative speed at which technology is adopted by an individual or organization. Technology transfer takes place in a social system that is influenced by social structure. So as per Rogers, a social system is described as a collection of interconnected units such as persons, informal groups, organizations, and/or subsystems that work together to solve problems in order to achieve a shared target (Rogers, 1983).

A five-stage model that outlined the innovative decision-making process was established by Everett Rogers in his theory of innovation diffusion. Knowledge comes in the initial step of this process where a person becomes informed about innovation and acquires a certain understanding of how it works. Why what and how are questions raised by individuals in this stage of the decision process to know more about technology (Rogers, 1983).

Then the persuasion step of the decision-making process, people develop a positive or negative perception or attitude towards the technology. So, peoples concerned with the technology actively seeks detailed information about it. As a result, it is affective or feeling based while the knowledge step is cognitive or knowing based. The next step is a decision where a person decides to choose or reject technologies based on analyzing its advantage and disadvantages. The persons also put the technology or innovations into practice in the implementation step. Finally, in the confirmation step, a person evaluates the results of an innovation decision already made (Rogers, 1983).

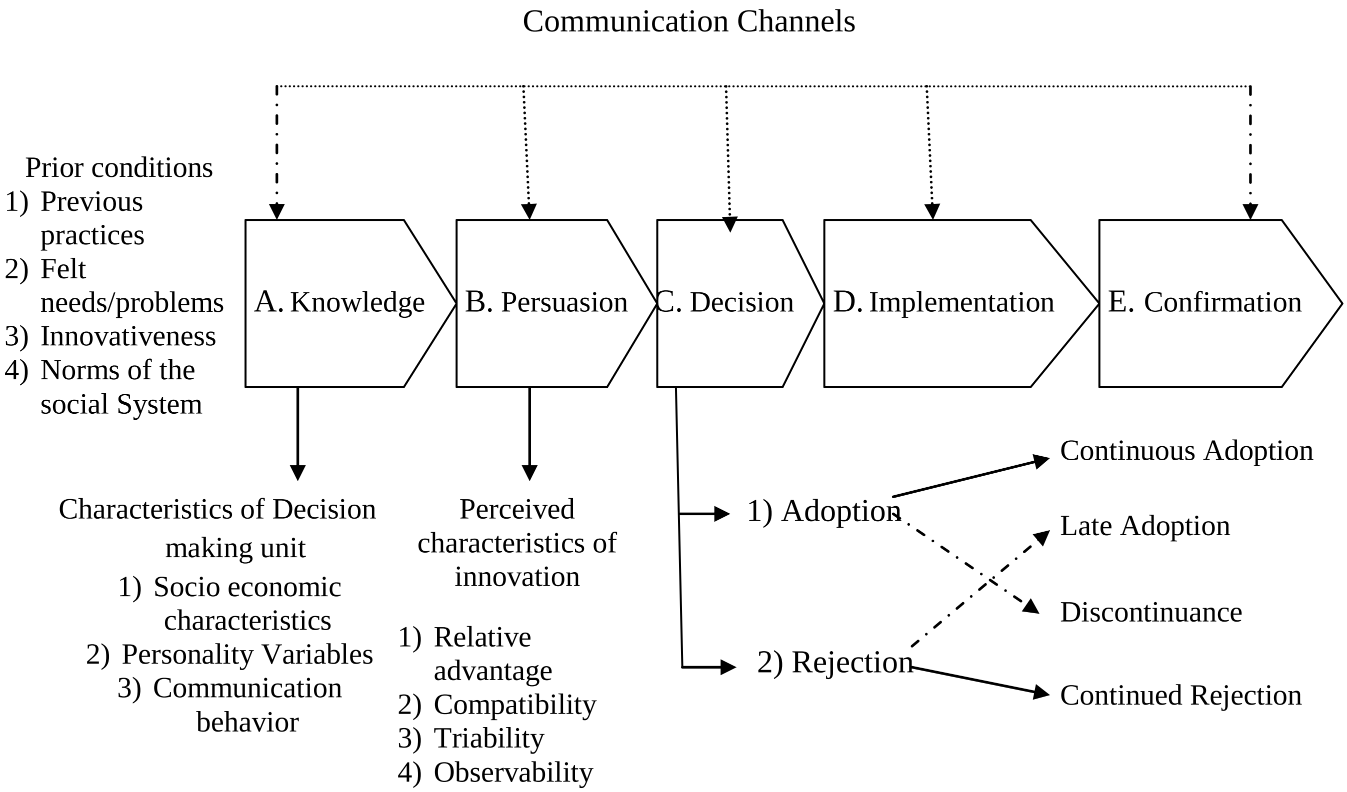

Figure 3: The innovation decision-making process adopted from Rogers's innovation diffusion theory (1983)

According to their innovativeness, technology adopters are grouped as innovators, early adopters, early majority, late majority, and laggards. Innovators are the pioneers to adopt technology such as CSA technologies. Whereas, early adopters follow deliberate acceptance in technology adoption and have the greatest levels of opinion leadership. Early adopters are encouraged to adopt technologies when the gains become evident. The late majority adopts new technology following the average member of a social system. Despite their concern regarding the technology and its results, they should adopt the technology due to the influence of economic necessity and peer pressure from their close social networks. In a social system, laggards are the last to accept new technologies. They are essentially traditional or isolated in social networks. In comparison to other types of adopters, innovators tend to be more well-educated, younger, wealthier, and socially rich (Rogers, 1983).

The speed of technology adoption is the length of time required for adoption by a certain social system. The speed of technology adoption is influenced by the five attributes of innovations namely relative advantage, compatibility, complexity, trialability, and observability. As a result, farmers adopt technologies such as CSA at varied times and speeds (Rogers, 1983). Based on the theory of innovation diffusion, this study investigates factors that influence the spread of CSA technologies in rice farming households over time.

2.5. Empirical Literature

2.5.1. The Practice of Climate Smart Agricultural Technologies

Climate-smart agricultural practices or technologies play a significant role to improve crop yields, farm income, and input use efficiency of many smallholder farmers including rice-producing households (Ha & Bac, 2021; Khatri-Chhetri et al., 2016). CSA practices in smallholder rice farming include integrated pest management, rice intensification, improved rice varieties, crop rotation, changing the sowing or harvesting calendar, minimizing the number of crop plantings, changing fertilizer and chemical use, changing crop variety, diversifying crops, soil and water management and weather risk management (Dung, 2020; Ha & Bac, 2021). With a particular interest in the climate-smart agricultural framework, this study investigates three CSA technologies, i.e. maintaining crop residue, use of organic manure or compost, and water management through constructing soil bunds to assess factors influencing farmers' adoption of those technologies and estimating the profitability of those adopted CSA technologies. For example, if maintaining crop residue is chosen for adoption, increases average agricultural yields in the long term through conserving soil. It also helps to preserve the environment through reduced soil erosion: and reduced greenhouse gas emissions.

Maintain Crop Residue

Crop residue maintenance is leaving the crop residues in the paddy cultivation area rather than bringing them elsewhere (FAO, 2014; Farooq & Siddique, 2015). FAO's (2014) definition of retention of crop residues uses 30% permanent organic soil cover as the minimum, but the best level of soil cover is area-specific. Crop residue helps to maintain and increase soil fertility and productivity. It protects crops from drought, and mulch cover also protects the soil from extreme temperatures (FAO, 2014). According to FAO (2014), Crop residue maintenance mitigates climate change via eradicating greenhouse gas emissions and sequestering carbon in soils and plant biomass. In addition, farmers who adopted it are more resistant to climate change. Crop residue maintenance increases agricultural yields in the short term and long term (Lungu, 2019; FAO, 2014; Farooq & Siddique, 2015).

Construct Soil Bund for Water Management

In agricultural as well as in rice farming fields both excess and too small water is unwanted. Therefore, excess water influence the soil functions, hamper plant growth and raise the possibility of nutrient runoff in the rice field. On the other side, too little water can have a damaging influence on rice crops and their capacity to absorb nutrients from the soil. So, to remove those gaps it needs to maintain the water balance (Bouman, Lampayan, & Tuong, 2007)**.** Water balance is the way of managing water by regulating or controlling the water used in watering crops by constructing soil bunds (Anuga et al., 2019; Sardar, Kiani, & Yasemin, 2020). Rice is a highly susceptible crop to water shortage and drought effect (when soil moisture content falls under saturation) during the flowering period. So, a drought at the flowering stage induces a reduction in paddy yield from increased spikelet sterility and consequently fewer grains. Rice farmers maximize rice yield through the effective and efficient use of water (Bouman, Lampayan, & Tuong, 2007).

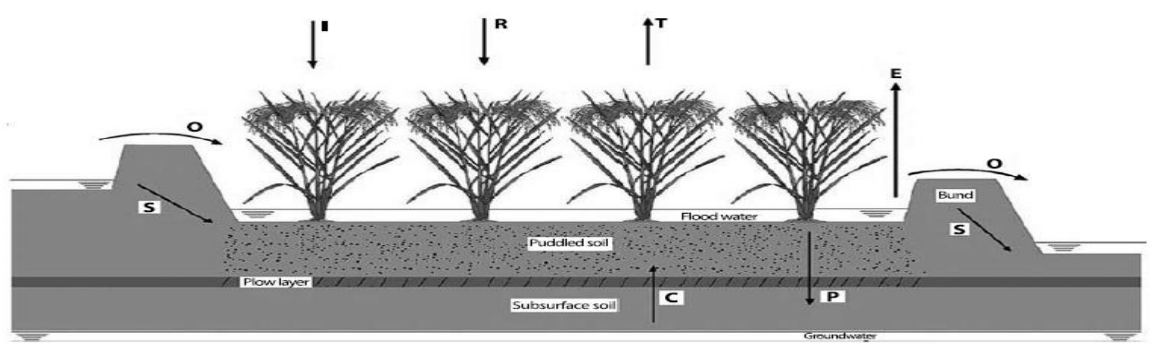

Figure 4: Water management of paddy fields in the plain through constructing soil bunds (Bouman, Lampayan, & Tuong, 2007)

Note: C = capillary rise, E = evaporation, I = irrigation, O = flow of the water over the bund, P = percolation, R = rainfall, S = seepage, T = transpiration

Use of organic manure or compost

Organic manure or compost obtained from animal dung, human waste, or vegetation matter maintains soil fertility and then improves agricultural productivity with minimal impact on the environment (Anuga et al., 2019).

2.5.2. Factors Influencing the Adoption of Climate-Smart Agricultural Technologies

Literature (Tran et al., 2019; Dung, 2020; Etim & Ndaeyo, 2020) has shown that there are many factors that influence smallholder rice-producing farmers' choice to adopt or not certain climate-smart agricultural technologies. Tran et al., (2019) investigate the choice of different packages of climate-smart agricultural technologies that are significantly determined by sex, age, working age family size, climate-related aspects, the paddy field characteristics, distance to markets, institutional factors including access to climate data, trust in agricultural extension workers' expertise, membership in social/agricultural groups and perception toward hazard in Vietnam rice farming.

Distance to markets is negatively linked to the adoption of climate-smart agricultural technologies but positively linked to access to climate data, trust in agricultural extension workers' expertise, and membership in social/agricultural groups in Vietnam rice farming. The working-age family size is negatively related to the chance of choosing water-saving techniques for rice cultivation in the Bac Lieu and Ha Tinh provinces of Vietnam. Rice farmers with big household sizes are not eager to choose climate-smart agricultural technologies for adoption in their rice farms (Tran et al., 2019).

Ha & Bac (2021) studies the factors influencing the adoption of climate-smart agriculture technology in northeast Vietnam rice farming. The findings showed that sex, educational background, main occupation, irrigated paddy field, accessibility of agricultural extension services, techniques of land preparation, credit loans, and rate of rice revenue have a positive influence on the adoption of Climate Smart Agricultural technologies.

On the other hand, the gender and age of the family head did not have a significant influence on the adoption of climate-smart agriculture practices in Vietnam's Mekong Delta rice production. Access to the market is inversely and significantly related to the rice farmers' choice to introduce yield management practices such as the rice intensification system, integrated pest management, enhanced rice variety, change in land uses with rice-peanuts/crop rotation with rice-shrimp, changing sowing or harvesting date, reducing the number of crop plantings, changing fertilizer and chemical use, changing crop variety, and diversifying crops (Dung, 2020). Age, education, household size, farm revenue, and access to information on climate change have a significant positive influence on farmers' willingness to adopt climate-smart agriculture practices by rice farmers in the Akwa Ibom state of Nigeria (Etim & Ndaeyo, 2020).

2.5.3. Profitability of Climate-Smart Agriculture

Profitability estimation is the analysis of the financial viability of CSA technologies adopted in the farm field (Wango, 2016). It is a relative measure of income/earnings from rice farming through adopting climate-smart agricultural technologies. Khatri-Chhetri et al. (2016) estimate the economic revenues of climate-smart agricultural technologies to smallholder farmers in the indo Gangetic plains of India. The finding showed that climate-smart agricultural technologies which include enhanced crop varieties for large amounts of yield, crop varieties best suited to survive with drought, surplus water, or high temperature, laser land leveling, zero tillage, crop residue maintenance, site-specific nutrient management, legume integration, and crops diversification adopted by the farmers significantly influenced the change in the whole yield in rice-wheat system. So, smallholder farmers can achieve higher yields and income by adopting various climate-smart agricultural practices and technologies.

Northeast Vietnam rice farmers who implemented climate-smart agricultural practices boost their yield or returns of rice crops by up to 14–21% or 0.7–1.1 tonnes over non-adopters. These CSA practices include the use of high-yielding rice varieties, the rice intensification system, drought-resistant varieties, and changing the sowing dates (Ha & Bac, 2021).

Study results obtained from Sardar, Kiani & Yasemin (2020) signify that farmers who adopt climate-smart agricultural technologies including shifting cropping time, zero or minimal tillage, water management techniques, improved crop varieties, and nutrient management options gained a higher yield of 44%kg per ha and larger farm earnings 48% US$ per ha than non-adopted farmers for rice-wheat crops in Punjab province of Pakistan. Ariani, Hervani & Setyanto (2018) evaluated the economic feasibility of climate-smart agricultural practices in irrigated rice fields in Banjarnegara, Purbalingga, and Banyumas Districts of Indonesia. They found that adopting climate-smart agricultural technologies increases rice grain yield by 0.7 -1.9 tons per ha.

The above reviews show that climate-smart agricultural practices/ technologies increase rice yield or productivity of smallholder farmers along with preserving the environment. However, there is a demand of doing more studies to broaden the currently existing knowledge base and to investigate extra dimensions of the benefits of smallholder farmers' adoption and profitability of climate-smart agricultural technologies in rice farming households.

2.6. Conceptual Framework

Climate-smart agricultural technologies, such as maintaining crop residue, use of organic manure or compost, and water management through constructing soil bunds can be adopted to enhance the agricultural productivity of smallholder rice farmers along with preserving the environment. The probability of smallholder rice farmers' decision to adopt CSA technology is determined by demographic and social, climatic and information, institutional and economic factors. Rice-producing farmers who adopt CSA technologies are expected to increase their agricultural profitability along with climate change mitigation and better climate adaptive capacity.

The figure below shows the relationships between the profitability of CSA technologies, the adoption of CSA technologies in rice farming, and different factors/independent variables /determining rice farming households' decision either to adopt or not the CSA technologies. The profitability of CSA technologies and the adoption of CSA technologies is the dependent variable. The conceptual framework for this study is shown below in Figure 5.

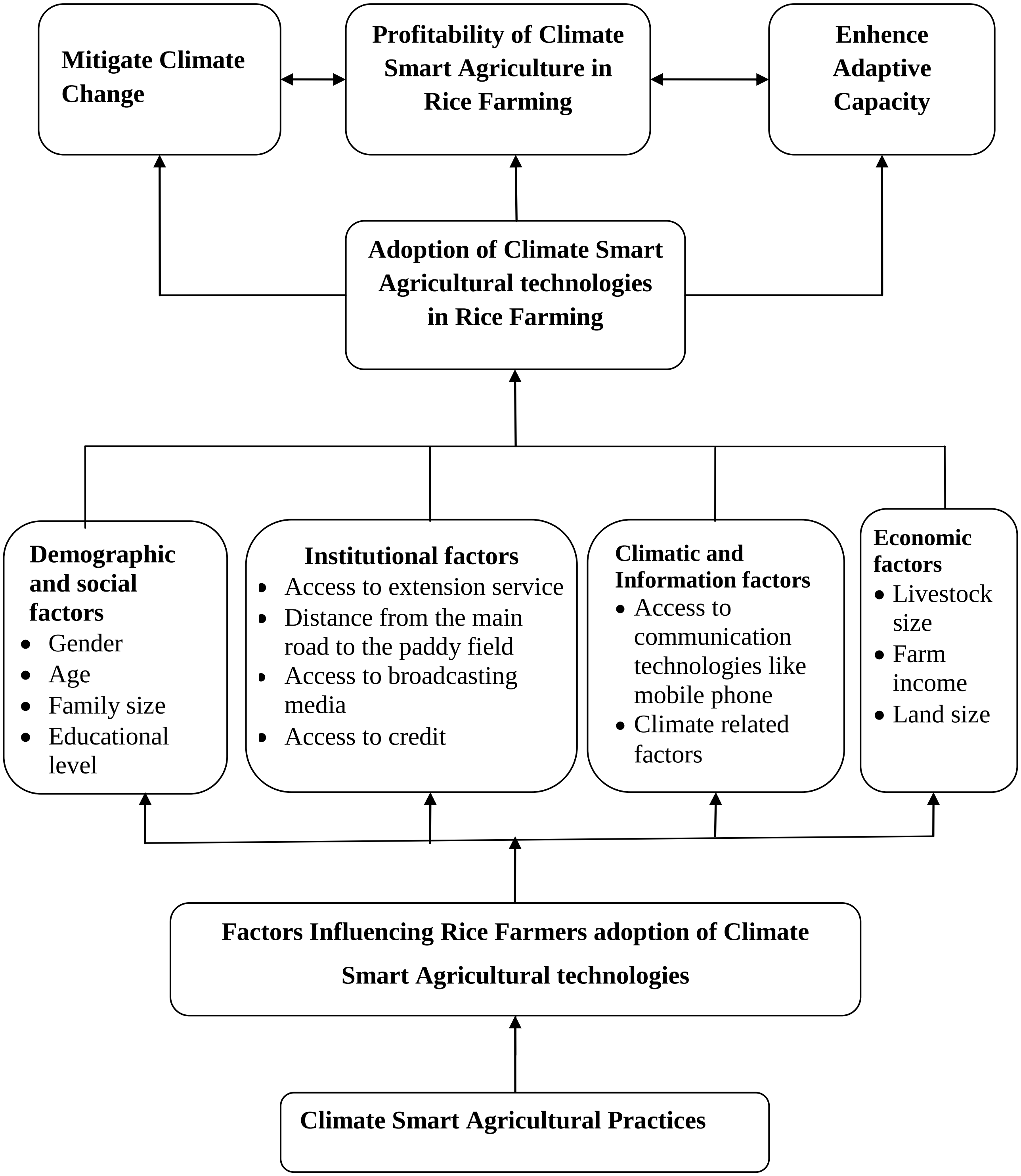

Figure 5: Conceptual framework of the study

Source: Slightly Adopted from Njuguna (2020)

CHAPTER THREE

METHODOLOGY OF THE STUDY

3.1. Description of Study Area

The research was done in the Fogera woreda[1] of the South Gondar Zone, Amhara regional state. The study area is also geographically situated at a GPS coordinate of 11°40' - 12°20' N latitude and 37°30' - 38°00' E longitude. It is located 625 kilometers to the northwest of Addis Abeba, 55 kilometers to the north of Bahir Dar, and 42 kilometers to the west of Debre Tabor cities along the main route from Addis Abeba to Gondar. The research area is bordered by Lake Tana on the west, Farta and Este woreda on the east, Dera woreda on the south, and Libo Kemkem Woreda on the north. According to the Woreda agriculture office, Woreda has 32 kebeles of which 30 were rural and 2 were urban and semi-urban.

Based on the Ethiopian Statistical Service Population Projection Size report by sex, area, and density (2022), Fogera Woreda has a total population of 300,473 of which 152,829 were male and 147,644 were female. It has a total area of 1111.43 square kilometers of land. Based on the data obtained from the Woreda agriculture office (2022), 76% of the topographic characteristics of the study area are plain or flat land. Whereas, 11% of the Woreda topography are mountainous, and also the remaining 13% are hills and valley. According to IPMS (2005), the altitude of the woreda is between 1774 to 2410 meters above sea level and it is also mostly categorized as Woinadega[2] agroecology.

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[1]Woreda is the administrative division of the government of the FDRE which is analogous to a district comprising numerous kebeles (Tekle, 2013).

[2]Woinadega is one of the traditional agroecological zones of Ethiopia which have altitude ranges of 1500 to 2300 masl , the mean annual rainfall ranges between 800 and 1200mm and also the mean annual temprature ranges between 17.5 and 20^{0}C (MoA, 1998). It is highly sutable for crop production and it also equivalents with the suptropical eological zone of the globe.

According to the Woreda agriculture office, the annual temperature of the Woreda varies from 10.30C to 27.20C as well as the annual rainfall also varies from 1103 mm to 1336 mm. Black clay soil (ferric Vertisols) is the dominant soil type in the plain which accounts for 65%, while orthic luvisols are commonly found in the med and high altitude areas.

The two main rivers, Rib and Gumara, are of great economic importance to the Woreda because they allow irrigation to produce horticultural products largely vegetables throughout the dry season. Fogera woreda was also well-known in livestock production in particular it is the home of the Fogera cattle breed (IPMS, 2005). Furthermore, Fogera is blessed with stunning natural resources with the ability to raise diverse seasonal and perennial crops. Teff, maize, finger millet, and rice were the major crops cultivated in Fogera woreda during the summer season. Whereas, onion and tomatoes were cultivated in the dry season via irrigation. As a result, mixed farming (crop with livestock) on fragmented landholding is commonly practiced in Fogera Woreda (Abebaw, 2019).

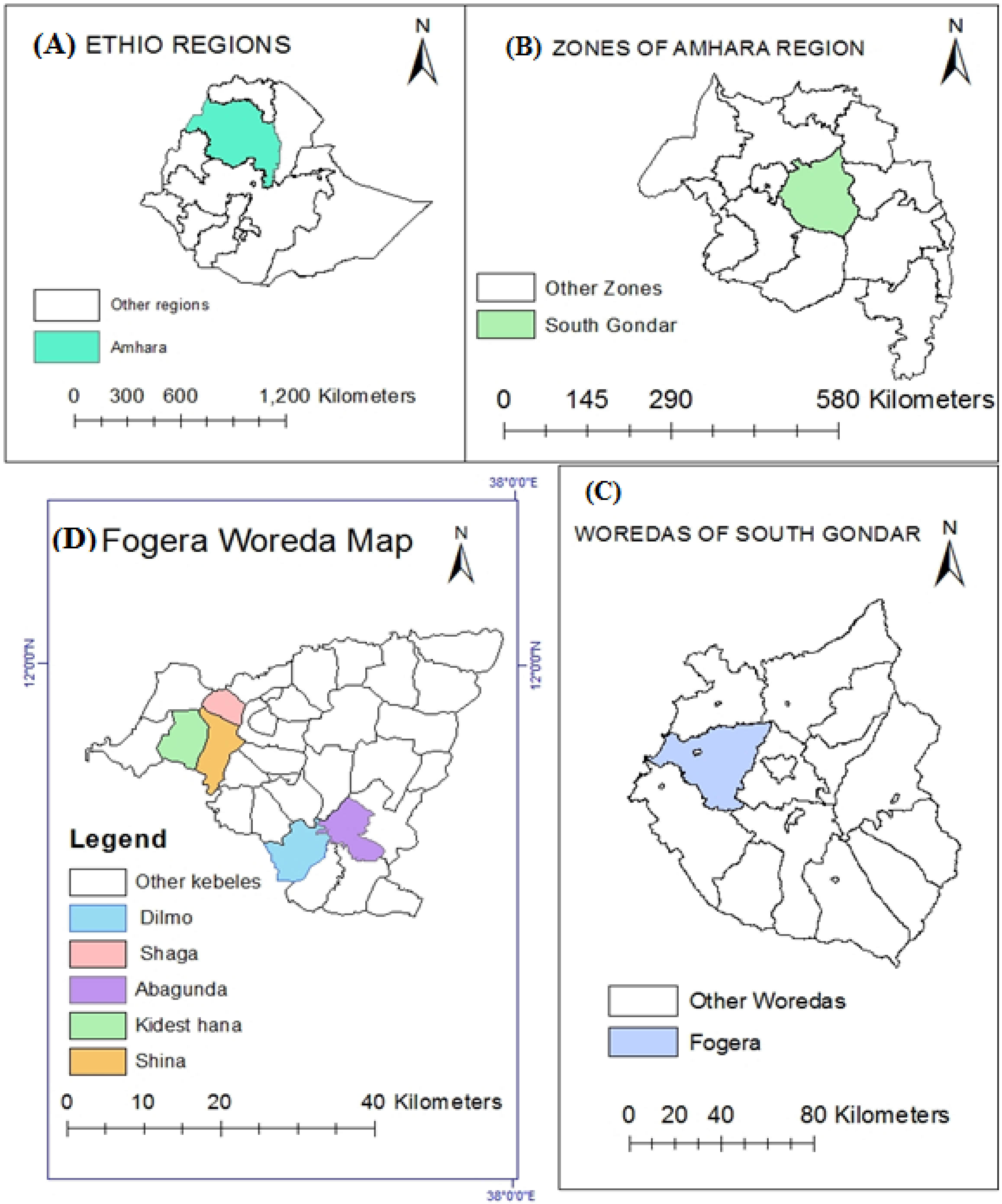

Figure 6: The map of the study area

Source: Arc GIS (2022)

3.2. Research Design and Approach

This study used a cross-sectional research design to examine factors influencing farmers' adoption and estimate the profitability of climate-smart agricultural technologies in rice farming households. Studies that survey a cross-section of the population to determine the prevalence of a phenomenon, problem, situation, attitude, or issue are best suited for a cross-sectional study design (Kumar, 2019). Both qualitative and quantitative research methods were also used for this study. For this reason, the mixed research method provides a better and more complete picture of a situation or phenomenon (Kumar, 2019).

3.3. Sampling Techniques and Sample Size

Fogera Woreda is among the areas which produce surplus crops and it is the primary rice producer in Amhara and Ethiopia (Hagos & Zemedu, 2015). Under this research, purposive and random sampling techniques were used to choose Kebeles[3] and sample smallholder rice farming households respectively.

Out of the total of 30 rural kebeles of Fogera Wereda, 14 of them are producing rice crops (Takele, 2010). Therefore, sample 5 kebeles were selected purposively from total rice-producing kebeles based on rice production potential, agro-ecology, time, and other physical factors. Purposively selected kebeles were Shina, Shaga, Kidest Hana, Abagunda Sendega, and Dilmo. The purposive sampling technique gives the best information about the aim of the study and is also helpful to explain a phenomenon or develop something about which merely a little is known (Kumar, 2019).

The respondents were selected randomly from climate-smart agriculture technology adopters and non-adopters of smallholder rice farming households. In random sampling, every respondent in the population has an equal opportunity of being chosen (Kumar, 2019). So, the researcher used a simple random sampling technique to get precise

[3]Kebele also usually known as farmers association or neighborhoods is the lowest elected administrative division of Ethiopia (FDRE, 2014).

information. The sample frame of this study was acquired in the agricultural office of Fogera woreda.

Therefore, as per the data gathered from Fogera woreda agricultural office (2022) Shina, Shaga, Kidest Hana, Abagunda Sendega and Dilmo have 2139, 1059, 1635, 810, and 647 total households respectively. The sample size was determined using the formula developed by (Yamane, 1967) with a 95% level of confidence.

$$n = \frac{\mathrm{N}}{1 + \mathrm{N(e)2}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(1)$$

Where: n = the sampled rice farming respondents

N = total number of rice farming households

e= level of precision with a 95% confidence interval

So, the total sample size became:

$$\text{n}=\frac{6290}{1+6290(0.05)2} = 6290/16.725 \approx \mathbf{376}$$

Table 1: Distribution of sampled rice farming household respondents by Kebele

No	Name of Kebeles	Total Area in (Km^2)	Distance from Woreda capital in (Km)	Total number of household	Number of sampled households
1	Shina	35.87	13	2139	128
2	Shaga	17.67	5	1059	63
3	Kidest Hana	37.28	18	1635	98
4	Abagunda Sendega	36.69	22	810	48
5	Dilmo	30.9	35	647	39
	Total	**158.41**		**6290**	**376**

Source: Fogera Woreda agriculture office (2022)

Whereas, six (6) respondents for key informant interviews from Woreda and Kebele agricultural offices were selected purposively to obtain depth information on the practice of CSA technologies and factors determining smallholder rice farming households' CSA technology adoption.

3.4. Data Collection

Pertinent quantitative and qualitative data were gathered to accomplish this research. Those pertinent data were gathered through questionnaires given to sampled respondents that produce rice together with key informant interviews with experts at the Fogera woreda and kebeles agricultural offices.

3.4.1. Questionnaire

This data-collecting tool was utilized by the researcher to gather data from respondents of selected rice farming households. The questionnaire includes structured and semi-structured questions to gather quantitative and qualitative data from the target population. It includes data about the selected rice farming household's demographic and social characteristics, as well as climatic, informational, institutional, and economic factors influencing farmers' adoption and profitability of climate-smart agricultural technologies.

3.4.2. Key Informant Interview

The researcher also employed in-depth interviews with key informants which provides rich and more intensive information from the informant. Since, it is useful to gain in-depth information and insight from knowledgeable people that cannot be obtained with other methods (Kumar, 2019). Accordingly, purposively selected 6 experts at the woreda and kebele agriculture offices were interviewed.

3.5. Methods of Data Analysis

The qualitative data collected were analyzed using content analysis. While quantitative data were analyzed using descriptive statistics and inferential statistics. Descriptive statistics such as frequencies, sum, means, standard deviation, and percentages were used to describe the economic, demographic, and social characteristics of smallholder rice farming households and institutional, climatic, and information factors. On the other hand, the binary logistic regression model was used to determine the effect of various factors influencing smallholder rice farmers' adoption of climate-smart agricultural technologies. The profitability of CSA was also estimated by using net return/profit and gross margin analysis

Furthermore, descriptive tests namely the chi-square test and t-test were used to observe the statistical association between the adoption of climate-smart agricultural technologies and the economic, demographic, and social status of smallholder rice farming households. Statistical packages such as Excel, SPSS version 23, and Stata version 14.2 were used to manage and analyze the collected data. The analyzed result was presented via different statistical tools such as tables and graphs.

3.5.1. Profitability Estimation

In this study, the profitability of the climate-smart rice production systems was estimated by using net return/profit and gross margin analysis. Net profit/return was calculated by subtracting the total production cost from the total farm income. Gross margin is the difference between the gross farm revenue/income gained through climate-smart agricultural practice (GFR) and the total variable cost (Oloyede et al., 2020; Wango, 2016).

That is;

GM = GFR – TVC .... (2)

TPC= TFC+TVC..(3)

Net Return= GFR-TPC..(4)

Where;

GM= Gross margin (birr/hectare)

GFR= Gross farm income/revenue of CSA package adopters (birr/hectare)

TVC=Total variable cost of rice production (birr/hectare)

TFC= Total fixed cost of rice production (birr/hectare)

TPC= Total rice production cost (birr/hectare)

$$\mathrm{GFR} = \frac{\sum_{i=1}^{n} \mathrm{QiPi}}{\text{Number of hectares}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots (5)$$

Where; Qi= The quantity of produced rice yield by the i^{th} farmer

Pi= The price of produced rice yield by the i^{th} farmer

$$TC = \frac{\sum_{i=1}^{n} QiPi}{\text{Number of hectares}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where; Qi= The total quantity of rice production input of the i^{th} farmer

Pi= The total amount of expenditure in birr of the i^{th} farmer

3.5.2. Model Specification

Factors influencing farmers' adoption of climate-smart agricultural technologies in rice farming households were analyzed using a binary logistic regression model in this study. Since the dependent variable is dichotomous and measured in terms of adopting and non-adopting CSA technologies by rice farming households to maximize their profitability. Although numerous statistical models such as logit and probit have been used to analyze binary outcomes. As a result of its simplicity and interpretability than the probit model (Gujarati, 2004), the binary logistic regression model is used in this study.

In binary logistic regression, the odds ratio is used to explain how the explanatory variable influences the smallholder rice farming households' adoption of CSA technologies. This model uses maximum likelihood estimation after transforming the dependent variable into logit. Following Gujarati (2004), the binary logistic regression model of the smallholder rice farmers' adoption of CSA technologies is specified as:

$$Pi = F(a+\sum BiXi) = \frac{1}{1+e^{-(a+\sum BiXi)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{7})$$

Where;

Pi= the probability that a rice farming household is adopting climate-smart agricultural technologies in their paddy field.

Xi= factors that affect the climate-smart agricultural technology adoption decision of rice farmers' (i.e. sex, age, family size, education level of farmers, land size, farm income, number of herd livestock, distance from the main road to the paddy field, access to extension service, access to broadcasting media, access to credit, climate-related factors and access to communication technologies like a mobile phone).

a= constant and B= The coefficient of the explanatory variable to be estimated

e= the base for the natural logarithm

Then;

$$Pi= \frac{1}{1+e^{-Zi}} = \frac{e^{Zi}}{1+e^{Zi}}$$ where; Zi= a+BiXi or in other word Zi= $a + \sum BiXi$ ------- **(**8)

Where (Pi) is the probability that the rice farming household adopts CSA technologies and (1-Pi) is the probability of the rice farming household not adopting CSA technologies. While the probability of rice farming households not adopting CSA technologies can be written as follows:

$$1-Pi= \frac{1}{1+e^{Zi}} \quad \text{-- (9)}$$

Then the odds ratio explains the ratio of the rice farming household's who adopt (Pi) and not adopt (1-Pi) CSA technologies.

$$\frac{Pi}{1-Pi}= \frac{1+e^{Zi}}{1+e^{-Zi}}= e^{Zi} \quad \text{--- (10)}$$

Hence; the logarithm of the odd ratio is written as follows:

$$Ln= Ln\left(\frac{Pi}{1-Pi}\right)= Ln\ (e^{a} + \sum_{i=1}^{n} BiXi)= Zi \quad \text{--(11)}$$

When the error term (ri) is taken into account, the logit model is expressed as:

$$Zi= a + \sum_{i=1}^{n} BiXi + ri \quad \text{-- (12)}$$

Zi is valued as 1 for rice farming households who adopt CSA technologies and 0 for households that are not adopting CSA technologies.

3.6. Description of Variables

Dependent variable

The dependent variables are the adoption and non-adoption decision of each climate-smart agricultural technology assuming that the rice farming households maintain or do not maintain crop residue, use or do not use organic manure or compost, and adopt or do not adopt water management through constructing soil bunds.

Independent variable

In this study, social and demographic, climatic and information, economic and institutional variables were factors influencing rice farming households' decision to adopt climate-smart agricultural technologies. The definitions of selected variables are given below.

1. Sex is one of the socioeconomic factors that could affect smallholder rice farmers' adoption of CSA technologies. The findings of Studies by Dung (2020) revealed that the gender of the household head did not have a significant influence on the adoption of CSA practices. On the other side, the study results of Tran et al., (2019) showed that gender has a negative relationship with climate-smart agricultural practices for rice farmers having smaller plots of rice fields. Whereas, it has a positive relationship with the climate-smart agricultural practice for a large plot of rice fields.
2. The adoption of climate-smart agricultural technologies by smallholder rice farmers is also influenced by the age of the household's head. Tran et al., (2019) argue that aged farmers are unable to choose CSA practices on their rice farms for adoption. Because they are less willing to make long-term investments in their paddy field and very risk-averse than younger farmers. Whereas, Etim & Ndaeyo (2020) discovered that choosing CSA technologies correlated positively with older farmers' decisions for adoption. So, older farmers' knowledge and experience in farming positively affect the adoption of climate-smart agricultural technologies.
3. The family size of farmers positively correlates with smallholder rice farmer adoption of climate-smart agricultural technologies in rice production (Etim & Ndaeyo, 2020). Farmers with large family sizes are more willing to adopt climate-smart agricultural technologies. Bigger family members show the availability of labor for rice production.
4. The education level of farmers positively correlates with smallholder rice farmer adoption of climate-smart agricultural technologies. Rice farmers who have accomplished a certain level of education have a higher likelihood to adopt climate-smart agricultural technologies, as indicated in the study findings by Dung (2020).

5. Land size has positive effects on smallholder rice farmers' adoption of climate-smart agricultural technologies in rice production (Dung, 2020). Rice farmers who owned a large area of land have a higher likelihood to choose and adopt CSA technologies.
6. Farm income positively correlates with the choice and adoption of climate-smart agricultural technologies through providing the necessary capital for investment (Tran et al., 2019).
7. Livestock size also has a positive influence on the decision of rice farmers to adopt or choose climate-smart agricultural technologies.
8. Distance from the main road to the paddy field negatively correlates with the choice and adoption of CSA technologies. So, smallholder rice farmers' paddy fields placed near the main road are more likely to adopt CSA technologies.
9. Access to extension services has a positive relationship with the likelihood of adopting climate-smart agricultural technologies (Dung, 2020; Tran et al., 2019).
10. Farmers with access to broadcasting media are more likely to adopt climate-smart agricultural technologies.
11. Access to credit has a positive relationship with the likelihood of choosing to adopt climate-smart agricultural technologies (Dung, 2020; Zegeye & Fikire, 2021).
12. Climate-related factors have a positive relationship with the likelihood of adopting climate-smart agricultural technologies. Rice farmers who noticed unpredictable climate change are more likely to choose and adopt climate-smart agricultural practices.
13. Farmers with access to communication technologies like mobile phones are more likely to adopt CSA technologies.

Therefore, in this study model estimation of the sex, age, and livestock size of the rice farming household head is expected to have either a positive or negative influence on farmers' adoption of climate-smart agricultural technologies in the rice farming household. The road distance is expected to have a negative influence on rice farming households' CSA technology adoption. Whereas, family size, education level of farmers, land size, farm income, access to extension service, access to broadcasting media, credit access, climate-related factors, and access to communication technologies like a mobile phone is also expected to have a positive influence on farmers' adoption of climate-smart agricultural technologies.

Table 2: Summary of the description of variables and their expected sign used in the binary logistic regression models

No	Variables	Definitions of Variable	Type of Variable	How Variables Inputted	Expected Sign
	Dependent				
1	Crop residue	Maintain crop residue	Dummy	1= if yes 0= if no	
2	Compost	Use of compost	Dummy	1= if yes 0= if no	
3	Soil bund	Construct soil bund	Dummy	1= if yes 0= if no	
	Independent				
1	Gender	Sex of the rice farming household head	Categorical	1 = Male 2=Female	–/+
2	Age	Age of the rice farming household head	Continuous	calculated in years	–/+
3	Family size	Number of families	Continuous	In number	+
4	Education level	The educational level of the household head	Dummy	1= Educated 2= Non-educated	+
5	Land size	Size of owned land	Continuous	In number	+
6	Farm income	Total farm income of household	Continuous	birr per year	+
7	Livestock size	Total livestock herd	Continuous	Total number of livestock in TLU[4]	–/+
8	Road distance	Distance from the main road to the paddy field	Continuous	Measured in Km	-
9	Access to extension	Households obtain extension service	Dummy	1= if they have access	+

[4] Tropical livestock unit (TLU) is the equivalent value of animals based on their biomass, subsistence and market value. The unit was 1 for cattle, 0.1 for sheep/goat, 0.5 for donkey/horse (Peden, et al., 2007; Lai, 2007). Whereas, the value of poultry is 0.05TLU (Lai, 2007).

No	Variables	Definitions of Variable	Type of Variable	How Variables Inputted	Expected Sign
	service				
10	Access to broadcasting media	Households used broadcasting media to access information	Dummy	1= if they have access	+
11	Access to credit	Households have the opportunity to credit service	Dummy	1= if they have access	+
12	Climate-related factors	Noticed unpredictable climate change	Dummy	1 = Yes	+
13	Access to mobile phone	The household who uses a mobile phone to access information	Dummy	1= if they have access	+

Source: Derived from the reviewed related literature (2022)

3.7. Reliability and Validity of the Data Gathering Instrument

Validity is the power of the data gathering tool to measure what is it designed to collect the desired data (Kumar, 2019). The data collection tool was developed depending on the study objectives of the research. Additionally, intense reviews were done for updating the designed tools. Furthermore, input from an academician who has better knowledge of the theme was obtained for the improvement of the instrument. Therefore, content validity was used in this study. It confirms whether or not the data gathering instrument covers all the areas of study (Kumar, 2019).

Reliability shows the accuracy, stability, predictability, and consistency of the data gathering instrument. Reliability can be determined through internal (split half technique) and external consistency (test/retest and parallel form of the same test) procedures (Kumar, 2019). In this study, the reliability of the data gathering instrument was tested through conducting a pilot study of 10% of the rice farming respondents in sampled Kebeles of Fogera woreda before carrying out the main research survey.

The overall reliability of this research data gathering instrument was measured by Cronbach"s alpha reliability statistics test whose result was 0.773. Cronbach's alpha coefficient value of the reliability test of this study indicates that the overall internal consistency of the data gathering instrument was acceptable. Since Chronbach's alpha measures the internal consistency of the data gathering instrument whose result ranges from 0 to 1. Thus, the smallest acceptable score of the reliability test from Chronbach's alpha coefficient is 0.7 (George & Mallery, 2019).

3.8. Ethical Considerations

Ethical considerations are a set of guiding principles that govern the design and practice of any research (Bhandari, 2021). Therefore, the researcher gathered valuable data from the target respondents by following the ethical principles of research as well as their culture and values were also respected. So, the purpose and objective of the study were clarified for the target respondents of rice farming households. The researcher also guaranteed the target rice farming respondents that their identity and the information obtained from them remained secure and confidential since their responses were used merely for academic purposes. Target rice farming respondents' willingness to fill out the questionnaire was assured near the beginning because this is a voluntary activity for them.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1. Descriptive Statistics

4.1.1. The Practice of CSA Technologies

According to data obtained from key informants (2022), rice was the leading and iconic crop cultivated during the period of the rainy season in sampled kebeles of Fogera woreda followed by maize. Finger- millet is also grown rarely in the upper sampled Kebeles of the district namely: Abagunda Sendega and Dilimo. Those sampled 5 kebeles were prominent in onion, maize, teff, and vegetable production in the dry season through irrigation. Similarly, in the autumnal season, various legumes like chickpeas and Lathyrus sativus (Grass pea) crops were produced. This finding relates to the previous study by Takele (2010). Thus, to enhance their productivity and profitability rice farming households of Fogera woreda were practicing CSA technologies in their paddy field.

The finding in Table 3 indicates that out of the total 376 sampled households 136 (36.2%) of rice farming household respondents maintain crop residue in their rice fields while 240 (63.8%) of them did not maintain crop residue in the paddy field. Similarly, 142 (37.8%) of the sampled total respondent use compost or organic manure for soil fertility improvement whereas 234 (62.2%) of the total respondents were non-adopters. Likewise, 207 (55.1%) of respondents had constructed soil bunds to manage water in their rice paddy fields but the rest of 169 (44.9%) did not.

Data obtained from key informants (2022) explained that like the residue of rice, the residue of other crops (such as irrigated onion crops) was also maintained in the rice field. According to their response residue of onion improves soil fertility in the plain more than other cereal crop residues which contributes to rice productivity. The rice farmers' main reason for maintaining crop residue was to reduce the input cost of fertilizer. Whereas, non-adopters refuse to maintain residue due to fear of the spread of weeds and the incubation of insects since the residue serves as a habitat for insect eggs if it was not immediately cultivated and mixed with soil.

The Kebele and Woreda key informant (2022) also added that the rationale of farmers to use organic manure or compost in their paddy fields was to reduce the cost of fertilizer and also enhance productivity by improving soil fertility. On the other hand, the motive of non-adopters was a shortage of livestock, labor, green leaves like Cordia Africana, and fear of health problems.

According to key informants, rice farming households also constructed soil bunds to manage water in their paddy fields which requires balancing water for ideal rice growth. Since too low and too high amounts of water in the paddy are not recommended for rice growth. An optimum amount of water also warms if it is stored for a stretched time which facilitates the infestation of Azolla[5] that needs frequent replacing. The bloom of Azolla holds the rice plant twisted and creates a suitable condition for pest and disease breeding. According to Hove (1989), the quick growth of Azolla might harm the growth of the rice crop and also suffocates the rice seedling. In other words, a dense Azolla carpet harms the rice tillering. Consequently, the rice farmer in the study area constructs a soil bund to manage water for better yield and profitability.

Table 3: The CSA technologies adopted by farmers and their frequencies

No	CSA technologies	Adopters		Non-adopters		Total sampled respondent
		No.	%	No.	%	
1	Maintain crop residue	136	36.2	240	63.8	376
2	Compost or organic manure	142	37.8	234	62.2	376
3	Construct soil bund	207	55.1	169	44.9	376

Source: Own survey (2022)

[5] Azolla is a water fern which used as a bio-fertilizer for rice cultivation since it has high nitrogen fixing ability, rapid growth and produce high biomass. It was introduced into Ethiopia from India during 2004 (Feyisa et al., 2008).

4.1.2. Demographic and Social Characteristics of Rice Farming Household

Demographic and social characteristics such as sex, age, marital status, family size, and educational level of sampled 376 households were analyzed to investigate their influence on farmers' adoption and profitability of climate-smart agricultural technologies in rice farming households.

In about 301 households (80.1%) of smallholder[6] rice farming households, both CSA adopters and non-adopters were male-headed while 75 (19.9%) were female-headed. This is an indication of males were the predominant household head in the study area. Of the crop residue adopter households, 75.7% of them were male-headed and 24.3% were female-headed. Likewise, 87% of adopters of water management via constructing soil bunds and 83.8% of compost or organic manure user households were male-headed. On the other hand, 82.5% of households that had not maintained crop residue in the paddy field were male-headed. 77.8% of non-compost or organic manure adopters and 71.6% of non-soil bund adopters were also male-headed. The decision of rice farming households to construct soil bunds for water management is statistically associated with their sex, according to the Pearson chi-square test ($X^2(1)>$ = 13.745, p = 0.000). On the contrary, there is no statistically significant correlation between the sex of rice farming households and their decision to maintain crop residue ($X^2(1)>$ = 2.488, p = 0.115) and apply compost or organic manure ($X^2(1)>$ = 2.009, p = 0.156) in the paddy field. Allocation of assets including land holding right among gender influence the adoption of agricultural technology (Wango, 2016).

The findings in Table 5 indicate that the average age of rice-framing household heads was 39.77 years with a standard deviation of 12.770 from the mean age. The mean age of rice farming household heads who maintain crop residue in their rice field was 37.03 years. While the mean age of household heads who had not adopted crop residue was 41.33 years. The mean age of rice farming household heads that adopt compost or organic manure as CSA technology for their rice field was 36.21 years. Whereas, non-

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[6] Smallholder is farmers who own smaller than 2 hectares of land (FAO, 2015).

organic manure or compost adopter household heads' mean age was 41.94 years. Furthermore, the mean age of rice farming household heads who manage water through constructing soil bunds was 37.53 years. While non-soil bund adopter household heads mean age were 42.53 years.

This result implies that non-CSA technologies adopter rice farming household heads were relatively older than adopters. The P value of the t-test indicates that there is a significant ($P<0.05$) mean difference between the age of crop residue adopters and non-adopters (t= 3.527). Similarly, there is a significant ($P<0.05$) mean difference between the age of adopters and non-adopters of compost (t= 4.468) and soil bund (t= 3.748) CSA technologies. Likewise, Tran et al., (2019) find out that older rice farmers are risk reluctant and unwilling to invest in their rice farms for the long term.

The average family size of rice farming households was 5.2 which is relatively more than the average Ethiopian countrywide rural family size of 4.6 persons per household (ESS, 2021). The mean family size of crop residue and organic manure or compost adopters were 5.75 and 5.71 respectively. Similarly, the mean family size of soil bund adopters was 5.68. On the other hand, the mean family size of both non-adopters of crop residue and non-adopters of compost or organic manure was 4.88. Likewise, non-adopters of soil bund had an average of 4.6 family size. These specify that non-CSA technology adopter rice farming households had fewer family sizes than adopters. Beyond and above, the rice farming households' family members based on the age category of below 15 years, from 15-64 years, and above 64 years was 2.29, 2.84, and 0.06 respectively. These findings explained that rice farming households in the study area had more family members who were included in the working-age population category of OECD (2022).

The P value of the t-test indicates that there is a significant ($P<0.05$) mean difference between the family size of the crop residue adopters and non-adopters of rice farming households (t = -4.628). In addition, there is a significant ($P<0.05$) mean difference between the family size of compost (t = -4.183) and soil bund (t = -5.701) adopters and non-adopters. The big family size of rice farming households implies the availability of labor for rice production. Similarly, Wango (2016) also revealed that big family sizes could also reduce the costs of crop production.

Regarding marital status, A high percentage of rice farming household heads (76.9%) were married. Whereas, 10.9%, 6.9%, and 5.3% of respondents were single, divorced, and widowed respectively. The Pearson chi-square test ($X^2(3)> = 3.241$, $p = 0.356$) result showed that there is no statistically significant association between the marital status of rice farming household heads and their decision to choose crop residue for adoption. Whereas, there is a statistically significant association between the marital status of rice farming households and their decision to use compost ($X^2(3)> = 11.232$, $p = 0.011$) and manage water through constructing soil bund ($X^2(3)> = 32.653$, $p = 0.000$) in the paddy field.

Regarding the educational level of rice farmers, as shown in table 4, 60.4% of the rice farming household head were non-educated. 29.8% of the household head have a primary level of education, 6.4% secondary, 2.1% technical and vocational education, and 1.3% degree and above. The analysis implies that more educated rice farming household heads were likely to adopt CSA technologies in their paddy field. The decision to maintain crop residue ($X^2(4)> = 17.024$, $p = 0.004$), use compost/organic manure ($X^2(4)> = 23.245$, $p = 0.000$), and manage water via constructing soil bund ($X^2(4)> = 10.638$, $p = 0.031$) in the paddy field are all statistically significantly associated with the educational level of the household head who farms rice.

Table 4: Descriptive statistics of demographic and social characteristics of rice farming households for categorical variables

Variable		Crop Residue				Compost				Soil Bund				Total respondent	
		Non-adopter		Adopter		Non-adopter		Adopter		Non-adopter		Adopter			
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Sex	Male	198	82.5	103	75.7	182	77.8	119	83.8	121	71.6	180	87	301	80.1
	Female	42	17.5	33	24.3	52	22.2	23	16.2	48	28.4	27	13	75	19.9
Educational status	Degree and above	4	1.7	1	0.7	2	0.9	3	2.1	3	1.8	2	1	5	1.3
	TVET	3	1.3	5	3.7	5	2.1	3	2.1	3	1.8	5	2.4	8	2.1
	Secondary	11	4.6	13	9.6	11	4.7	13	9.2	10	5.9	14	6.8	24	6.4
	Primary	60	25	52	38.2	53	22.6	59	41.5	37	21.9	75	36.2	112	29.8
	None educated	162	67.5	65	47.8	163	69.7	64	45.1	116	68.6	111	53.6	227	60.4
Marital status	Single	26	10.8	15	11	27	11.5	14	9.9	21	12.4	20	9.7	41	10.9
	Married	190	79.2	99	72.8	178	76.1	111	78.2	110	65.1	179	86.5	289	76.9
	Divorced	14	5.8	12	8.8	11	4.7	15	10.6	22	13	4	1.9	26	6.9
	Widowed	10	4.2	10	7.4	18	7.7	2	1.4	16	9.5	4	1.9	20	5.3

Source: Own survey (2022)

Table 5: Descriptive statistics of demographic and social characteristics of rice farming households for continuous variables

Variable		Crop Residue		Compost		Soil bund		Total
		Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	
Age	Mean	41.33	37.03	41.94	36.21	42.53	37.53	39.77
	Std. Deviation	14.090	9.466	13.122	11.341	14.227	10.976	12.770
Family members below 15 years of age	Mean	2.07	2.67	2.12	2.56	1.96	2.56	2.29
	Std. Deviation	1.369	1.224	1.403	1.206	1.315	1.317	1.348
The family member from 15-64 years of age	Mean	2.75	3.01	2.68	3.12	2.56	3.07	2.84
	Std. Deviation	1.422	1.496	1.192	1.772	1.117	1.646	1.453
The family member above 64 years of age	Mean	0.09	0.02	0.08	0.04	0.08	0.05	0.06
	Std. Deviation	0.283	0.147	0.267	0.202	0.276	0.215	0.245
Total Family size	Mean	4.88	5.75	4.88	5.71	4.60	5.68	5.20
	Std. Deviation	1.988	1.590	1.871	1.836	1.670	1.940	1.898

Source: Own survey (2022)

4.1.3. Economic Characteristics of Rice Farming Household

Economic characteristics of smallholder rice farming households were also assessed to indicate their influence on farmers' adoption and profitability of climate-smart agricultural technologies in Fogera woreda of the Amhara region. The economic factor includes land holding, land size, livestock size, total farm income, and off-farm income earned by rice farmers.

Land Holding

The finding in table 6 showed that the majority (85.9%) of smallholder rice farming households were landholders. While 14.1% of respondents not had the right to hold land rather they use land by renting and shared cropping from landholders. From crop residue adopters, 96.3% of smallholder rice farming households were landholders. Likewise, 96.5% of compost adopters and 96.1% of soil bund adopters of rice farming households were landholders. Whereas, 20% of non-crop residue adopters not had the right to hold land. Similarly, 20.5% of non-compost or organic manure adopters and 26.6% of non-soil bund adopters not had the right to hold land.

This result implies that the majority of CSA technology adopter smallholder rice farming households were landholders compared to non-adopters. There is a statistically significant association between the land holding of smallholder rice farming households and their decision to maintain crop residue (X2(1)> = 19.102, p = 0.000), use compost (X2(1)> = 21.071, p = 0.000) and construct soil bund (X2(1)> = 39.811, p = 0.000) in the paddy field. Similarly, the study result of Tran et al., (2019) and Dung (2020) explained that rice farmers who own/hold the land had more tendency to adopt CSA technologies.

Table 6: The number and percentage of rice farming households' land-holding status

CSA technologies		Landholding of household			
		Yes		No	
		No.	%	No.	%
Crop Residue	Non-adopter	192	80	48	20
	Adopter	131	96.3	5	3.7
Compost	Non-adopter	186	79.5	48	20.5
	Adopter	137	96.5	5	3.5
Soil Bund	Non-adopter	124	73.4	45	26.6
	Adopter	199	96.1	8	3.9
Total sampled household		323	85.9	53	14.1

Source: Own survey (2022)

Furthermore, 18 (4.8%), and 26 (7%) smallholder households were the holder of grazing and plantation land respectively in addition to cultivated land.

The mean size of the total land holding of smallholder rice farming households in the study area was 0.677 ha which is relatively less than the Ethiopian national as well as the Amhara regional average land holding of 0.84ha and 1.15ha respectively (Central Statistical Agency, 2021b). The sum of the areas of the land held by the sampled respondent was 254.625ha. The major part of the land was used for crop cultivation (mean = 0.657 hectares and sum= 247 hectares) while the mean land holding size of households who hold grazing land and plantation lands were 0.09 and 0.011 hectares respectively. The sum of the areas of held grazing land was 3.5ha and also the sum of the areas of held plantation land was 4.125ha.

Table 7**:**Total size of the land held by rice farmers

Area of land	Sum	Mean	Standard Deviation
Cultivated	247	0.657	0.403
Grazing	3.5	0.009	0.044
Plantation	4.125	0.011	0.043
Total	254.625	0.677	0.425

Source: Own survey (2022)

The mean number of parcels of rice farmland that sampled households cultivated was 1.58 while the sum of parcels was 594. The average area of the paddy field cultivated by sampled smallholder rice farming households in the study area was 0.653 hectares. The sum of areas of the paddy field cultivated by the sampled respondents was 245.375ha. The mean area of the paddy field cultivated by crop residue adopter households in 1.71 parcels was 0.719ha.

Whereas, the mean area of the paddy field cultivated by non-adopters of crop residue was 0.615ha. Non-adopters of crop residue also cultivated an average of 1.51 parcels of paddy fields. The average area of paddy fields cultivated by compost adopters was 0.75ha on an average of 1.85 parcels of land. On the other hand, non-adopters of compost or organic manure cultivated an average 0.593ha area of rice farmland and an average of 1.42 parcels of paddy field. Furthermore, soil bund adopters cultivated an average 0.704ha area of paddy field and an average of 1.81 parcels of paddy field. While an average of 0.59ha area of paddy field on the 1.3 parcels of rice farmland was cultivated by non-adopters of soil bund.

Therefore, these result confirms that household that hold and cultivated a large area of land is more likely to adopt CSA technologies. The P value of the t-test for land size indicates that there was a statically significant ($P<0.05$) mean difference between crop residue adopters and non-adopters of rice farming households ($t=-6.611$). Similarly, the P value of the t-test for land size cultivated by rice farming households indicates that there was a statistically significant ($P<0.05$) mean difference between compost ($t = -6.018$) and soil bund ($t = -6.914$) adopters and non-adopters.

Table 8: The area of paddy fields cultivated for rice production

CSA technologies		Number of parcels of rice farmland			The area of cultivated paddy field		
		Sum	Mean	Std. Deviation	Sum	Mean	Std. Deviation
Crop Residue	Non-adopter	363	1.51	0.825	147.625	0.615	0.236
	Adopter	232	1.71	0.827	97.750	0.719	0.242
Compost	Non-adopter	333	1.42	0.758	138.875	0.593	0.205
	Adopter	262	1.85	0.878	106.500	0.750	0.268
Soil bund	Non-adopter	221	1.30	0.629	99.750	0.590	0.198
	Adopter	374	1.81	0.904	145.625	0.704	0.264
Total		594	1.58	0.830	245.375	0.653	0.243

Source: Own survey (2022)

Income from Crop Production

Descriptive statistics results shown in table 9 found that respondents cultivated the average area owned, and rented in land for crop production was 0.627 and 0.048 ha respectively. Sampled respondents in the study area also cultivated 0.165 ha average area of shared-in land and 0.022 ha of shared-out land. Sampled households produced an average of 3609.089kg amount of crop on owned land and an average180.027kg amount of crop on rented-in land. They also produced an average amount of 490.559 kg crop in shared-in land and 88.165 kg crop in shared-out land.

Sampled households that maintain crop residue produce the highest average amount of 4752.059kg crop in 0.788ha owned land compared with non-adopters. The average amount of crop produced in 0.773 ha owned land by compost user households was 4725.704kg crop. Similarly, households that construct soil bunds to manage water harvested an average amount of 4440.18kg crop in 0.753 ha owned land.

In the rented-in land, farmers who maintain crop residue produced an average amount of 242.427kg crop. The average amount of 290.634kg and 183.72kg crop was produced by compost adopters and soil bund adopters respectively in rented-in land. Compost or organic manure adopters produce an average amount of 491.268kg crop in shared-in land. The average amount of 92.56kg crop was produced by crop residue adopter households in shared-out land. Similarly, the average amount of 100.211kg and 132.059kg crops were produced in shared-out land by compost users and soil bund technology adopter households respectively. Therefore, rice farming households that adopt CSA technology harvested the highest amount of crop in owned, rented-in, and shared-out land.

From the produced crop, the average amount of 268.91 kg crop was sold by the sampled respondent. The highest amount of crop was sold by CSA technology adopters from their annual production. As a result crop residue adopters sold 362.132kg crop. 291.761kg and 276.522kg crop was sold by compost and soil bund adopter households respectively.

The mean quantity of overall crop produced by sampled respondents was 4502.407 kg and their average overall production income in birr was 138050.8. The highest mean amount of overall crop produced by crop residue adopters was 5495.515kg and their average income in birr was 177198.86. Likely, compost or organic manure adopters also annually produced an average of 6158.169 kg amount of overall crop and their income in money was 180662.89 birr. Soil bund adopters annually produced an average amount of crop 5416.401kgand their income in monetary value was 162777.37 birr. Generally, CSA technology adopters earn the highest amount of income from crop production than non-adopters.

Table 9: The amount of crop produced in different land holding titles of the smallholder household

		Crop residue		Compost or organic manure		Soli bund		Total
		Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	
Size of own hold land for crop production in ha	Mean	0.536	0.788	0.538	0.773	0.473	0.753	0.627
	Std. Deviation	0.384	0.351	0.376	0.373	0.356	0.375	0.391
Quantity of crop	Mean	2961.406	4752.059	2931.485	4725.704	2591.124	4440.18	3609.089

produced in own cultivated land in Kg	Std. Deviation	2963.624	2258.675	2936.888	2339.953	2252.97	3033.282	2859.47
The area rented-in land for crop production in ha	Mean	0.044	0.055	0.038	0.065	0.053	0.044	0.048
	Std. Deviation	0.136	0.184	0.132	0.185	0.169	0.143	0.155
The amount of crop income produced in rented-in land in Kg	Mean	144.667	242.427	112.906	290.634	175.503	183.72	180.027
	Std. Deviation	451.512	984.705	373.659	1014.546	685.176	702.210	693.695
The area of shared-in land for crop production in ha	Mean	0.194	0.113	0.183	0.136	0.215	0.124	0.165
	Std. Deviation	0.229	0.177	0.233	0.178	0.239	0.183	0.215
The amount of crop income produced in shared-in land in Kg	Mean	563.458	361.912	490.128	491.268	533.55	455.459	490.559
	Std. Deviation	699.211	656.488	692.855	687.802	665.936	708.766	690.033
The area of shared out land for crop production in ha	Mean	0.016	0.033	0.0235	0.019	0.019	0.024	0.022
	Std. Deviation	0.065	0.09	0.08	0.067	0.077	0.074	0.075
Quantity of crop produced in shared ou land in Kg	Mean	63.292	132.059	80.855	100.211	82.781	92.56	88.165
	Std. Deviation	265.956	376.245	284.054	353.233	327.881	298.51	311.67
The amount of crop sold in kg from the produced	Mean	216.083	362.132	255.041	291.761	259.586	276.522	268.91
	Std. Deviation	391.378	630.276	466.032	541.642	440.097	537.541	495.55
The total quantity of crop produced in kg	Mean	3939.646	5495.515	3497.628	6158.169	3382.899	5416.401	4502.407
	Std. Deviation	5631.556	2444.674	2117.89	7008.632	2294.23	5964.177	4787.96
Total crop production income in birr	Mean	115866.896	177198.86	112192.18	180662.89	107764.4	162777.37	138050.8
	Std. Deviation	70129.06	81450.27	67856.93	80353.74	74962.6	75425.51	79959.5

(Own Survey,2022)

Income from Livestock Production

The average number of livestock owned by sampled smallholder rice farming households was 4.85 TLU and their average estimated price was 73748.24 birr. The crop residue adopter respondents owned an average of 5.7051 TLU with an average estimated price of 90770.9559birr. Whereas, non-adopters of crop residue owned an average of 4.3644 TLU with an average estimated price of 64102.0417birr. The compost or organic manure adopters respondents owned an average of 6.5773 TLU and their average estimated price was found to be 99329.1549 birr. Non-adopters of compost owned an average of 3.8008 TLU whose average estimated price was 58224.7863 birr. The rice farming households who adopted soil bunds owned an average of 5.9141 TLU which has a 90582.4155 birr average estimated price. Non-adopters of soil bund owned an average of 3.5451 TLU which has a 53128.8757 birr average estimated price.

This result explained that smallholder rice farming households that had higher livestock assets increased the probability of adopting CSA technologies. Specifically, the highest number of livestock owners used organic manure as a CSA technology than those who own less livestock. Dube (2016) also revealed that livestock was a vital potential source for organic manure preparation. Similarly, Wango (2016) also revealed that the availability of livestock resources enables a farmer to adopt CSA technologies. The P value of the t-test for crop residue ($t= -4.012$), compost ($t=-8.595$), and soil bund ($t= -7.357$) indicates that there was a statistically significant ($P<0.05$) mean difference in the number of livestock owned between the adopters and non-adopters of smallholder rice farmers.

Table 10: Income from livestock production and total farm income

CSA technologies		Number of livestock in TLU		The estimated price of livestock		Total farm income of a household in birr	
		Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Crop Residue	Non-adopter	4.3644	3.441	64102.0417	50001.031	188687.1917	173199.412
	Adopter	5.7051	2.911	90770.9559	52856.107	313092.9044	407276.085
Compost	Non-adopter	3.8008	3.034	58224.7863	45287.602	192035.6453	273737.367
	Adopter	6.5773	3.042	99329.1549	53873.886	302318.4507	296217.413
Soil Bund	Non-adopter	3.5451	2.882	53128.8757	41739.232	160973.6450	109547.871
	Adopter	5.9141	3.278	90582.4155	54560.353	293048.3816	363818.238
Total		4.85	3.319	73748.24	52571.836	233685	287081.92

Source: Own Survey (2022)

The mean annual farm income among the rice farming households was found to be 233685 birr. The mean annual farm income of sampled respondents who maintain crop residue was 313092.9044 birr while the mean annual farm income of soil bund adopters was 293048.3816 birr. Whereas, the mean annual income of the compost or organic manure adopters was 302318.4507 birr. The finding of result showed that the mean annual farm income of CSA technology adopters was higher than non-adopters. The P value of the crop residue (t= -3.393), compost (t= -3.671) and soil bund (t= -4.955) t-test for the mean annual farm income of smallholder rice farmers indicates that there was a statistically significant ($P<0.05$) mean difference between the adopters and non-adopters.

The descriptive statistics finding presented in table 11 also showed that 27.7% of smallholder rice farming households obtained additional income from off-farm activities while 72.3% of the respondent not gained income from off-farm activities. 26.6% of households who had not maintained crop residue participated in off-farm activities. While 30.1% of crop residue adopters participated in off-farm activities. On behalf of compost or organic manure, 26.8% of adopters and 28.2% of non-adopters participated in off-farm activities. Similarly, 34.9% of non-adopters and 21.7% of adopters of soil bund also participated in off-farm activities.

The study founds that the mean annual off-farm income of sampled respondents was 5278.3511 birr. The mean annual off-farm income of smallholder farmers that maintain crop residue was 6518.0882 birr while non-adopters earn 4575.8333 birr income from off-farm activities. Smallholder households that use organic manure or compost in their paddy field earn 4596.9718 birr mean annual income from off-farm activities while non-adopters also gained 5691.8376 birr. The mean annual off-farm income of soil bund technology adopter households was 4316.8116 birr. On the other hand, the mean annual off-farm income of non-adopters of soil bund technology was 6456.0947 birr. The P value of the crop residue (t= -1.591), compost (t= 1.035) and soil bund (t= 1.953) t-test for the mean annual additional income from off-farm activities of smallholder rice farmers also indicates that there was no statistically significant ($P>0.05$) mean difference between the adopters and non-adopters.

Table 11: Income from off-farm activities

CSA technologies		Amount of income from off-farm in birr		Additional income from the off-farm?			
				Yes		No	
		Mean	Std. Deviation	No.	%	No.	%
Crop Residue	Non-adopter	4575.8333	9078.931	63	26.3	177	73.8
	Adopter	6518.0882	12491.384	41	30.1	95	69.9
Compost	Non-adopter	5691.8376	11230.332	66	28.2	168	71.8
	Adopter	4596.9718	9070.341	38	26.8	104	73.2
Soil Bund	Non-adopter	6456.0947	11149.715	59	34.9	110	65.1
	Adopter	4316.8116	9799.27	45	21.7	162	78.3
Total		5278.3511	10468.009	104	27.7	272	72.3

Source: Own survey (2022)

4.1.4. Institutional Factors Influencing the Adoption of CSA Technologies

The result presented in table 12 showed that the majority (71.8%) of total respondents obtained extension service on CSA technology adoption for their rice fields. The remaining 28.2% of respondents had not gotten extension services. The result also showed that 89.7% of smallholder rice farming households who adopted crop residue had access to extension services. 85.2% of organic manure or compost adopters and 77.3% of soil bund adopters of smallholder rice farming households had gotten extension services. Whereas, 61.75 of non-adopters of crop residue adopters of smallholder rice farming households had access to extension service. Likewise, 63.7% of non-adopters of organic manure or compost and 65.1% of non-adopters of soil bund had access to extension service. So, the findings of this result signify that CSA technology adopters gain better extension service than non-adopters.

The Pearson chi-square test showed that there is a statistically significant association between access to extension services and the adoption of crop residue ($X^2(1)> = 33.713, p = 0.000$), compost ($X^2(1)> = 20.247, p = 0.000$) and soil bund ($X^2(1)> = 6.847, p = 0.009$). Extension service contributes a vital role to spread CSA technologies for rice farming households that enhance their sustainable agricultural productivity and profitability (Njuguna, 2020). The main extension service provider for smallholder rice farming households was government (49.6%), followed by other farmers (33.7%) and NGOs (16.7%). The respondent contacted extension service providers on an average frequency of 3.1 per season.

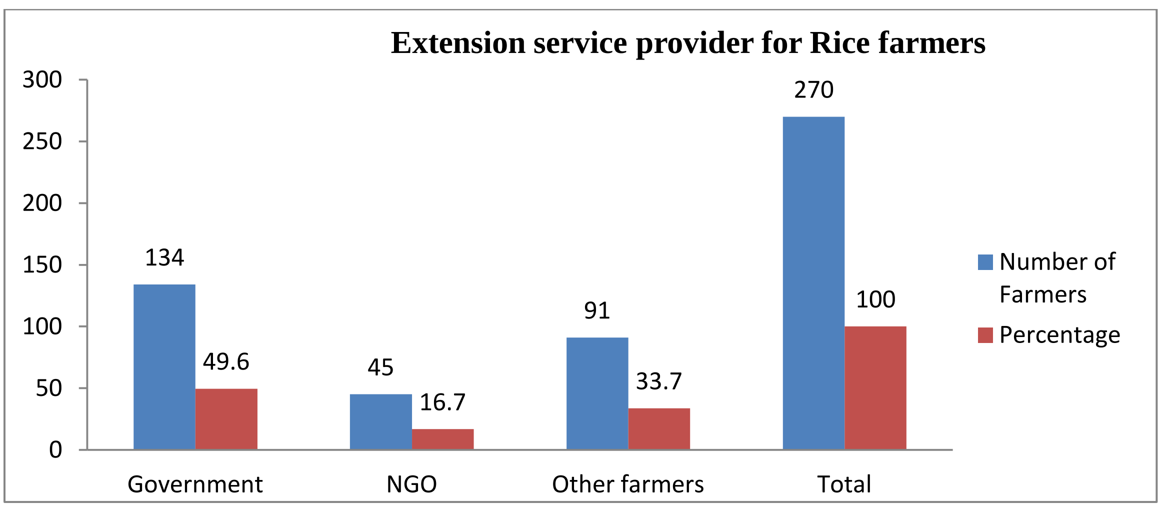

Figure 7: Extension service provider for rice farmers

Source: Own survey (2022)

Regarding broadcasting media access, 69.4% of the total household respondents accessed broadcasting media. Whereas, the remaining 30.6% of smallholder rice farming households had no media access. The finding showed that 67.6% of crop residue adopters, 70.4% of organic manure or compost adopters, and 69.1% of soil bund adopters of smallholder rice farming households had accessed broadcasting media. While 70.4% of non-adopters of crop residue, 68.8% of non-adopters of organic manure or compost, and 69.8% of non-adopters of soil bund had also accessed broadcasting media.

The chi-square test showed that there is no statistically significant association between access to media and the adoption of crop residue ($X^2(1)> = 0.314$, $p = 0.575$), compost ($X^2(1)> = 0.109$, $p = 0.741$) and soil bund ($X^2(1)> = 0.024$, $p = 0.877$). Of those types of broadcasting media accessed, radio was the main source of information for 79.7% of household respondents while 4.6% of the respondent also accessed television. Whereas, the remaining 15.7% of respondents accessed both radio and television to get information about CSA technologies.

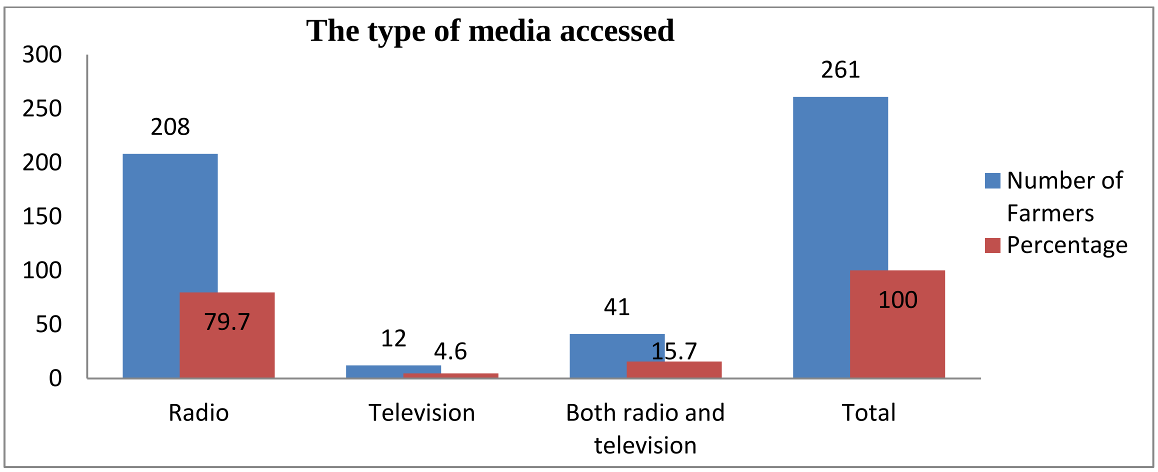

Figure 8: The type of broadcasting media accessed by rice farmers

Source: Own survey (2022)

The result shown in table 12 found that about 66.5% of smallholder rice farming households had access to credit while about 33.5% did not have access to credit. The household survey result also found that 77.2% of crop residue adopters, 71.1% of organic manure or compost adopters, and 69.6% of soil bund adopters had access to credit. Whereas, 60.4% of non-adopters of crop residue, 63.7% of non-adopters of compost, and 62.7% of non-adopters of soil bund also had access to credit. This implies that respondents who had access to credit were more likely to adopt CSA technologies. Among respondents who had access to credit, 59.5% of them had credit opportunities from credit and saving institutions. While the remaining 33.3% and 7.2% of respondents had credit opportunities from local money lenders and banks respectively.

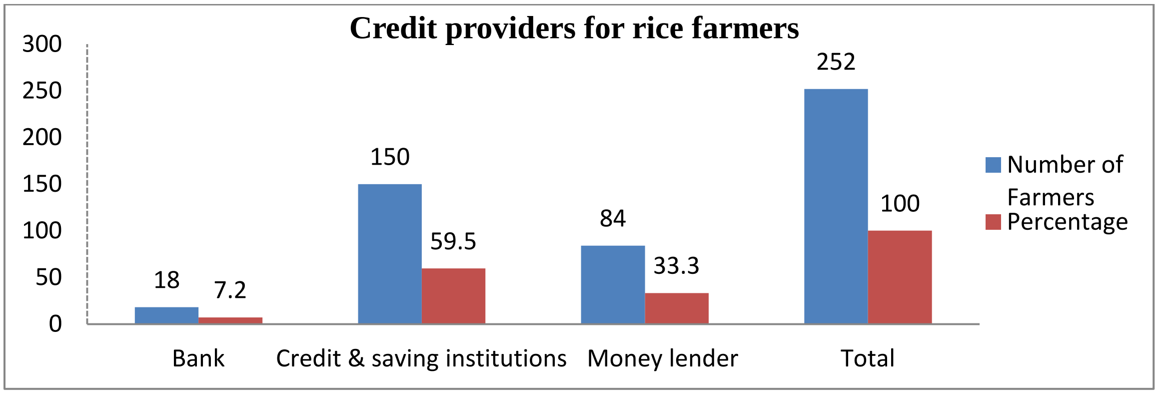

Figure 9: Credit service providers for rice farmers

Source: Own survey (2022)

The Pearson chi-square test result for access to credit showed that there is a statistically significant association with rice farming households' decision to adopt crop residue ($X^2(1)>$ = 10.982, p = 0.001) for their rice field. Whereas, the chi-square test result for access to credit also showed that there is no statistically significant association with rice farming households' decision to adopt compost ($X^2(1)>$ = 2.202, p = 0.138) and soil bund ($X^2(1)>$ = 1.956, p = 0.162) for their rice field. The study result of Dung (2020) revealed that rice farmers who have access to credit were more likely to adopt CSA practices.

Table 12: Descriptive analysis of institutional factors

Variable			Crop residue		Compost		Soil bund		Total respondent
			Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	
Access to an extension service	Yes	No.	148	122	149	121	110	160	270
		%	61.7	89.7	63.7	85.2	65.1	77.3	71.8
	No	No.	92	14	85	21	59	47	106
		%	38.3	10.3	36.3	14.8	34.9	22.7	28.2
Broadcasting media access	Yes	No.	169	92	161	100	118	143	261
		%	70.4	67.6	68.8	70.4	69.8	69.1	69.4
	No	No.	71	44	73	42	51	64	115
		%	29.6	32.4	31.2	29.6	30.2	30.9	30.6

Access to credit	Yes	No.	145	105	149	101	106	144	250
		%	60.4	77.2	63.7	71.1	62.7	69.6	66.5
	No	No.	95	31	85	41	63	63	126
		%	39.6	22.8	36.3	28.9	37.3	30.4	33.5
Distance from the main road to paddy field in km		Mean	13.57	12.69	14.40	11.35	11.88	14.37	13.25
		Std. Deviation	9.25	8.22	9.77	6.83	7.06	10.02	8.89

Source: Own survey (2022)

As shown in table 12, the overall mean distance from the main road to the paddy field was 13.25 km. The average distance from the main road to the paddy field of crop residue adopter and non-adopter rice farming households were 12.69km and 13.57km respectively. Organic manure or compost adopter rice farming households' average distance from the main road to the paddy field was 11.35km while non-adopters average distance was 14.40km. Similarly, soil bund adopter rice farming households' average distance from the main road to the paddy field was 14.37kg. Non-adopters of soil bund were situated at 11.88km average distance from the main road. This result implies that adopters of CSA technologies such as crop residue and organic manure or compost were closest to the main road but not soil bund adopters.

The P value of the t-test for distance from the main road to the paddy field shows that there was no statistically significant ($P>0.05$) mean difference between the crop residue adopters and non-adopters in the study area(t= 0.948). Whereas, the P value of compost (t= 3. 553) and soil bund (t=-2.826) t-test for distance from the main road to the paddy field shows that there was a statistically significant ($P<0.05$) mean difference between adopters and non-adopters.

4.1.5. Climate and Information Factors Influencing the Adoption of CSA Technologies

The result presented in table 13 on communication technologies like a mobile phone showed that 62.5% of respondents had their mobile phone. Whereas, 37.5% of respondents in the study area had no mobile phone. 75.7% of crop residue adopter rice farming respondents had their own mobile phones. Likewise, 79.6% of compost adopters and 70% of soil bund adopters also had their own communication technologies like mobile phones. On the other hand, 55% of non-adopters of crop residue and 52.1% of non-adopters of compost or organic manure also had their own mobile phone. Correspondingly, 53.3% of non-adopters of soil bund also had their own mobile phone. This result showed that respondents who had communication technologies like mobile phones were more likely to get information about CSA technologies. The Pearson chi-square test results for access to communication technologies like a mobile phone that there is a statistically significant association with rice farming households' decision to adopt crop residue ($X^2(1)> = 15.925$, $p = 0.000$), compost ($X^2(1)> = 28.392$, $p = 0.000$) and soil bund ($X^2(1)> = 11.196$, $p = 0.001$).

Furthermore, the descriptive statistics in the table also showed that 72.6% of smallholder rice farming households observed unpredictable climate change in their surrounding while 27.4% of the respondent was not observed. The 79.4%of crop residue adopter rice farming respondents had perceived unpredictable climate change. Likewise, 83.1%of compost adopters and 81.2%of soil bund adopters also had perceived unpredictable climate change. On the other hand, 68.8% of non-adopters of crop residue and 66.2% of non-adopters of compost or organic manure also observed unpredictable climate change. Correspondingly, 62.1%% of non-adopters of soil bund also observed unpredictable climate change. This signifies that respondents who observed unpredictable climate change were more likely to adopt CSA technologies. The chi-square test result for observing unpredictable climate change showed that there is a statistically significant association with households' decision to adopt crop residue (X2(1)> = 16.939, p = 0.000), compost (X2(1)> = 12.629, p = 0.000) and soil bund (X2(1)> = 4.961, p = 0.026) in the paddy field.

Table 13: Descriptive analysis of Climate and information factors

Variable			Crop Residue		Compost		Soil Bund		Total respondent
			Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	
Access to mobile phone	Yes	No.	132	103	122	113	90	145	235
		%	55	75.7	52.1	79.6	53.3	70	62.5
	No	No.	108	33	112	29	79	62	141
		%	45	24.3	47.9	20.4	46.7	30	37.5
Observed unpredictable climate change	Yes	No.	165	108	155	118	105	168	273
		%	68.8	79.4	66.2	83.1	62.1	81.2	72.6
	No	No.	75	28	79	24	64	39	103
		%	31.3	20.6	33.8	16.9	37.9	18.8	27.4

Source: Own survey (2022)

4.1.6. Profitability of CSA Technologies in Rice Farming Household

In this section, the profitability of adopting climate-smart agricultural technologies in the rice farming household of Fogera woreda was examined through gross margin and net profit. The gross margin of CSA technology adopters was computed as the difference between their farm income/revenue and variable cost per unit area. While net profit/return is also calculated as the difference between farm income/revenue and overall cost per unit area. Sampled respondents cultivated a total of 245.38 ha and an average 0.65 ha area of rice farming land during the period of the rainy season. That sampled rice farming household cultivated a maximum of 4 plots of paddy field and a minimum of 1 plot of land.

4.1.6.1. Costs of Rice Production in Adopted CSA Technologies

The production cost of sampled rice farming households per unit area in a year was calculated to estimate the profitability of adopted CSA technologies in the study area. These rice cultivation costs were variable and fixed. The estimated rent value of rice cultivation land was included in the fixed cost of production. On the other hand, variable costs of rice production consisted of organic manure or compost, fertilizer, seed, herbicides, labor, and animal power. The majority of rice farmers had prepared their own compost or manure but no one bought compost from others. As a result, the cost of organic manure or compost was estimated based on the price/wage of labor in days. Whereas, fertilizer cost also consisted of the total quantity of chemical fertilizers applied in the rice field. Seed costs were the total amount of seed needed to sow in the rice field that can be brought or own produced. Herbicides were the total amount of herbicide chemicals used to control weeds in the paddy field by rice farmers. Labor costs of rice production for land preparation, water management, weeding, harvesting, trashing, and winnowing also incorporated that household's family labor costs, hired labor, and exchange labor costs. Whereas, animal labor costs consisted of owned and hired animals' costs of production. Thus, the labor cost was estimated based on the price/wage of labor in days while animal power is the price of oxen per day and the price of a donkey in days.

The finding in table 14 showed the average total production cost of rice farming households per hectare of climate-smart agricultural technologies. The average total production cost of sampled rice farming households was 53209.05 birr per hectare. The average total production cost of rice farming incurred by farmers due to not adopting crop residue was 50618.09 birr per hectare. Whereas, the average total production cost of crop residue adopters was 57121.99 birr/ha. The average total production cost of compost and soil bund adopter rice farming households was 56992.16birr/ha and 54493.49birr/ha respectively. Whereas, the total production cost of rice farming incurred by farmers due to not adopting compost and soil bund was 50307.87 birr/ha and 51333.88 birr/ha respectively.

Whereas, the result in table 14 also revealed that the average total variable cost of sampled rice farming households was 31073.58 birr per hectare. The average total variable cost of crop residue and compost adopters was 32453.76 birr/ha and 32931.41 birr/ha respectively. While rice farming households that construct soil bunds to manage water incurred the average total variable costs of 32143.69 birr/ha.

As shown in table 14, the 22135.47 birr/ha for a year costs of the rent value of land occupied the biggest share of total costs of the sampled rice farming respondent. The next biggest expenses of rice farming households in a year were labor cost (11678.45 birr/ha), fertilizer (9106.06 birr/ha), and seed (5794.76 birr /ha) respectively. Among labor costs, the cost of weed (6416.42 birr/ha) was the largest expense of sampled rice farming respondents. Whereas among rice farming costs, the lowest rice production cost of 57.26 birr/ha of the sampled respondents was herbicide cost. The next smallest rice farming costs of sampled respondents were costs of own prepared compost and animal power 1090.58 and 3346.47 birr/ha respectively.

Table 14: Costs of rice production for each CSA technology in 1 ha rice paddy field

Cost of rice production		Crop residue Non-adopter	Crop residue Adopter	Compost Non-adopter	Compost Adopt	Soil bund Non-adopter	Soil bund Adopter	Total
Fixed cost								
Estimated rent value of land per 1 ha		20458.39	24668.24	20659.01	24060.75	21822.56	22349.80	22135.47
Variable cost								
Self-prepared compost	Quantity of labor in days	8.14	13.24	0.52	22.76	10.41	10.01	10.17
	Total cost in birr	868.42	1426.09	51.85	2445.07	1060.65	1111.07	1090.58
Fertilize	Quantity in kg	193.56	202.81	190.28	206.34	190.23	202.06	197.25
	Total cost in birr	8944.62	9349.87	8767.24	9547.89	8770.43	9335.97	9106.06
Seed	Quantity in kg	193.45	192.89	192.53	194.13	190.90	194.82	193.22
	Total cost in birr	5771.48	5829.92	5755.36	5846.15	5706.42	5855.28	5794.76
Herbicide	Quantity in liter	0.11	0.23	0.04	0.31	0.18	0.14	0.16
	Total cost in birr	41.05	81.74	13.83	113.90	65.76	51.43	57.26
Animal power cost								
Plowing	Quantity of oxen days	14.88	14.94	14.49	15.44	14.41	15.24	14.90
	Total cost in birr	1576.29	1678.67	1561.12	1690.05	1559.10	1656.79	1617.08
Trashing	Quantity of oxen days	9.46	9.91	9.48	9.84	9.91	9.45	9.64
	Total cost in birr	1014.67	1117.24	1035.03	1082.25	1071.08	1044.88	1055.53
Transporting	Quantity donkey in a day	7.19	5.73	5.00	8.69	7.08	6.28	6.61
	Total cost in birr	729.21	590.28	510.17	887.32	714.79	645.84	673.87
Overall Animal power cost	Quantity	31.52	30.58	28.98	33.97	31.40	30.97	31.14
	Total cost in birr	3320.17	3386.19	3106.32	3659.62	3344.96	3347.50	3346.47
human labor cost								

Water management	Quantity of labor in days	9.56	7.17	10.27	6.45	0.87	13.91	8.61
	Total cost in birr	1074.75	863.32	1205.40	710.33	89.22	1607.90	990.52
Land preparation	Quantity of labor in days	15.23	15.56	14.98	15.86	15.39	15.34	15.36
	Total cost in birr	1751.94	1837.34	1764.39	1814.08	1742.16	1815.97	1785.96
Weeding	Quantity of labor in days	54.25	57.12	56.37	54.12	55.77	55.13	55.39
	Total cost in birr	6088.74	6911.30	6564.03	6223.94	6204.31	6561.72	6416.42
Harvesting	Quantity of labor in days	12.18	12.92	12.46	12.49	12.31	12.59	12.47
	Total cost in birr	1371.18	1544.45	1432.15	1450.70	1349.47	1502.35	1440.20
Trashing and winnowing	Quantity of labor in days	8.64	9.44	8.73	9.25	9.43	8.63	8.96
	Total cost in birr	927.35	1223.53	988.30	1119.72	1177.94	954.51	1045.34
Overall human labor cost	Quantity of labor in days	99.86	102.21	102.81	98.17	93.77	105.61	100.80
	Total cost in birr	11213.95	12379.95	11954.28	11318.78	10563.11	12442.44	11678.45
Total variable cost in birr		30159.70	32453.76	29648.86	32931.41	29511.33	32143.69	31073.58
Total rice production cost in birr (variable and fixed)		50618.09	57121.99	50307.87	56992.16	51333.88	54493.49	53209.05

Source: Own survey (2022)

4.1.6.2. Gross Farm Revenue/Income (GFR) of Rice Production in Adopted CSA Technologies

Harvested rice has paddy and straw yield. The paddy yield consisted of on average 70% of grain and 30% of husk yield (Takele, 2010). The husk of paddy yield was removed by processing through a milling machine. Constantly, husk yield was gone to the rice processors because they refused to offer for rice farmers (Takele, 2010). As a result, rice farmers earned their revenue from selling paddy yield alone. Due to that, in these study return generated from paddy yield and straw yield of the rice production were considered for the estimation of profitability.

The mean amount of paddy rice yield produced by sampled rice farming households was 5351.295 kg per hectare and the monetary value of the average paddy yield revenue was 168775.5 birr per hectare. Whereas, the average amount of straw yield produced by the sampled respondent was 94.34 shekim[7] per hectare[8]. The sampled rice farming households' mean revenue produced from straw yield was 5553.45 birr per hectare. The average gross farm revenue earned by sampled rice farmers from rice production was 174328.9 birr per hectare.

As shown in table 15, the average quantity of paddy and straw yield produced by crop residue adopters were 6124.737 kg/ha and 101.95 shekim/ha respectively. As a result, crop residue adopter rice farming households earned a gross income of 199554.5 birr/ha. Non-adopter of crop residue also earned an average of 4839.16kg/ha of paddy yield, 89.3 shekim/ha of straw yield, and 157625.768 birr/ha of gross farm income from rice production. The rice farming household that used compost as a CSA technology earned an average of 6101.061 kg/ha of paddy yield, 100.939 shekim/ha of straw yield, and 199200.1 birr/ha of gross farm income from rice cultivation. Non-compost user households also earned an average of 4776.317kg/ha of paddy yield and 89.28 shekim/ha of straw yield. As a result, none compost user households' gross farm income from rice cultivation was 155255.8 birr/ha.

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[7] Shekim is a traditional measuring unit of straw yield equal to the amount of straw tied with a rope having a 2m circumference (Takele, 2010) that can be carried by a person.

[8] A hectare is equivalent with 4 Timad.

The rice farming household that constructs soil bunds to manage water earned an average of 5802.925kg/ha of paddy yield, 100.25 shekim/ha of straw yield, and 189496.7 birr/ha of gross farm income from rice cultivation. The rice farming household that was non-adopter of soil bund earned an average of 4691.96 kg/ha of paddy yield and 85.71 shekim/ha of straw yield. As a result, non-adopter of soil bund earned 152185.5 birr/ha of gross farm income from rice cultivation.

Table 15: The amount of yield, revenue, profit, and gross margin earned from rice production through adopting CSA technologies within an average 1 ha area of land

	Crop residue		Compost		Soil bund		
Profit	Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	Total
Paddy yield in kg	4839.16	6124.737	4776.317	6101.061	4691.96	5802.925	5351.295
Paddy revenue in birr	152427.38	193464.8	149972.3	193294.7	147112	183614.5	168775.5
Straw in shekim	89.3	101.95	89.28	100.939	85.71	100.25	94.34
Straw revenue in birr	5198.39	6089.678	5283.55	5905.399	5073.474	5882.225	5553.45
Total revenue (Straw+Paddy)	157625.768	199554.5	155255.8	199200.1	152185.5	189496.7	174328.9
Gross margin	127466.07	167100.77	125606.95	166268.68	122674.17	157353.00	143255.34
Profit (net return)	107007.68	142432.53	104947.94	142207.92	100851.61	135003.20	121119.87

Source: Own survey (2022)

4.1.6.3. Profit of Rice Production in Adopted CSA Technologies

The result in table 15 showed the profitability of rice farming in different climate-smart agricultural technologies.

Gross margin

The gross margin of rice production obtained through adopting the CSA technologies was calculated by subtracting the total variable costs of production from gross farm revenue. The result also showed that the gross margin of sampled rice farming households was 143255.3 birr/ha. The rice farming household that maintains crop residue earned the highest gross margin of 167100.77 birr/ha while non-adopter of crop residue earned 127466.07 birr/ha. Compost or organic manure user rice farming households earned the highest gross margin of 166268.68 birr/ha than non-users who gained 125606.95 birr/ha. Similarly, rice farming households that construct soil bunds to manage water earned a gross margin of 157353 birr/ha. The rice farmers who did not construct soil bunds to manage water also earned a gross margin of 122674.17 birr/ha. This result revealed that rice farming households who adopted CSA technologies earned the highest gross margin.

Net profit

The net profit or return of CSA technologies was computed by subtracting the total costs of production from gross farm revenue earned from rice production. The result also showed that the net profit or return of sampled rice farming households was 121119.87 birr/ha. The rice farming households who maintain crop residue earned the highest net profit of 142432.53 birr/ha while non-adopters of crop residue earned 107007.68 birr/ha. Compost or organic manure user rice farming households earned the highest net profit of 142207.92 birr/ha than non-users who gained 104947.94 birr/ha. Similarly, rice farming households that construct soil bunds to manage water earned a net profit of 135003.20 birr/ha. The rice farmers who did not construct soil bunds to manage water also earned a net profit of 100851.61 birr/ha.

These results indicated that non-adopters earn less net profit as well as revenue than CSA technologies adopters. A related result from the previous study by Arun et al., (2016) showed that rice farming households in Indo-Gangetic plains obtain a high amount of yield by practicing CSA technologies in their paddy field. The study result of Adesakin & Oluwatusin (2017) also revealed implementing improved agricultural technology by farmers was a productive business enterprise. In addition, the northeast Vietnam rice farmers who implemented climate-smart agricultural practices could decrease the amount of seed sown in the paddy field and also boost their yield or returns of rice crops by up to 14 to 21% or 0.7 to 1.1 tonnes over non-adopters (Ha & Bac, 2021).

4.2. Econometric Analysis of Factors Influencing Smallholder Farmers' Adoption of CSA Technologies

4.2.1. Model Validity Test

In econometric analysis, before conducting binary logistic regression analysis to evaluate factors influencing the adoption of CSA technologies in the smallholder rice farming household of Fogera Woreda, a variety of tests for an explanatory or independent variable was carried out to prove the validity of the model.

Multicollinearity along with explanatory variables was tested by using the Variance inflation factor (VIF) for continuous variables. The test result presented in Appendix II verifies that there was no problem of multicollinearity because the VIF result was smaller than 10 and the tolerance result was above 0.2 (Shrestha, 2020). Whereas, multicollinearity along with categorical/Dummy explanatory variables was verified by the Pearson correlation matrix. There was no issue with multicollinearity as evidenced by the Pearson correlation coefficient shown in Appendix III, which was less than 0.8. As a result, the value of the Pearson correlation test result above 0.8 showed that strong relationship among variables (Shrestha, 2020).

The Wald chi2 test value for the binary logistic regression models for crop residue, compost, and soil bund is 73.28, 88.14, and 88.96 respectively. The result shows that all variables included in each logit model statistically significantly influence the probability of the adoption of CSA technologies at a 1% significant level. The Pseudo R^2 value of crop residue, compost, and soil bund models are 0.2220, 0.2510, and 0.2152 respectively. The value of the estimated model implies that 22.2% of the total variation in the dependent variable/maintain crop residue was explained by the independent variable. The estimated Pseudo R^2 model value of compost implies that about 25.1% of the total variation in the dependent variable/using compost was explained by the independent variable. The estimated model value soil bund implies that 21.52% of the total variation in the dependent variable/constructing soil bund was explained by the independent variable.

4.2.2. Determinants of Smallholder Farmers' Adoption of Climate-Smart Agricultural Technologies

In this section, a binary logistic model was applied to estimate the determinants of smallholder rice farmers' adoption of CSA technologies in the study area. The dependent variables were either constructing or not soil bunds to manage water; using or not using compost; maintaining or not maintaining crop residue in the paddy field for rice production. The researcher employed a logistic regression model to estimate the effects of explanatory variables on the adoption of each CSA technology (soil bund, compost, crop residue). Farmers who constructed or not constructed soil bund structures were considered as "adopter" and "non-adopter" respectively; farmers who applied and not applied compost or organic manure in the paddy field were considered as "user" and "non-user" respectively. Similarly, farmers who maintained or not maintained at least 30% of crop residues in the paddy field are considered as "adopter" and "non-adopter" respectively.

As shown in table 16, out of 13 independent variables included in the model, 5 of them (namely sex, age, total family size, road distance, and log of income) were found to be statistically significant with the adoption of soil bund construction to manage water. Likewise, six (6) explanatory variables (namely; access to the phone, age, education level, livestock (TLU), road distance, and log of income) were found to be statistically significant for using compost/organic manure. Similarly, six (6) explanatory variables (namely; sex, access to extension service, access to the phone, age, livestock (TLU), and log of income) were found to be statistically significant for the adoption of maintaining crop residue. As a result, among explanatory variables, those merely have statistically significant and strong relations with the adoption of CSA technologies to be incorporated in the discussion.

Sex of Rice Farming Household Head

The finding presented in table 16 shows that the sex of the household head (being male) is found to be statistically significant ($P<0.01$) and has a positive effect on the adoption of soil bunds for water management, but statistically significant at ($P<0.05$) and has a negative effect on the adoption of crop residue in smallholder rice farming households. The odd ratio indicated that being a male household head increases the probability of practicing /adopting soil bund by a factor of 2.4198 as compared to female household heads. On the contrary, being a male household head decreases the probability of practicing crop residue maintenance by a factor of 0.4229 as compared to female household heads. The marginal effect value indicated that holding other variables constant, as being male household head increases, the adoption of soil bund work for water management increases by 16.78% in smallholder rice farming households. The result is analogous to the study finding by Njuguna (2020) that revealed that male was more likely to adopt water management because males have high capability and resource for land management. Beyond this, female-headed households have multiple roles (Zeleke et. al., 2022) and spent their time on home activities (Asfaw & Neka, 2017). Tran et.al (2019) also revealed that male rice farming household head who owned large plots of rice paddy field was more likely to adopt water-saving techniques like constructing soil bund.

On the contrary, holding other variables constant, as being a male household head, the adoption of maintaining crop residue decreases by 15% in smallholder rice farming households. This result implies that female household heads left crop residue for soil fertility improvement than male-headed ones. The male-headed household owns a large amount of livestock than female-headed ones (Debela, 2016) and deploys crop residue for animal feed (Gilo & Berta, 2016). The previous study by Njuguna (2020) also argues that female-headed household was more conscious of climate-smart agricultural technologies.

Extension Service Access

The other important factor which affects the adoption of CSA technologies is access to agricultural extension services. The result shown in table 16 indicated that access to extension service was found to be statistically significant ($P<0.01$) and has a positive influence on the adoption of crop residue. The odd ratio value indicated that as agricultural extension service increases, maintaining crop residue increases by a factor of 3.4043. The marginal effect value of 0. 2022 indicated that holding the other variables constant, as extension service increases, the likelihood of maintaining crop residue increases by 20%. This implies that the provision of extension services enhances the understanding and tendency of smallholder rice farming households to adopt CSA technologies including crop residue retention. This result is analogous to the study finding of Dung (2020) and Njuguna (2020). On the other hand, Tran et al., (2019) discovered that the frequency of extension contact has not influenced CSA technology adoption but the quality of obtained extension service. Accordingly, extension service providers play a vital role in guiding rice farmers on how to apply CSA technologies in their paddy fields.

Access to Communication Technologies Like Mobile Phone

Access to communication technologies like the mobile phone is among the key factors influencing the decision of rice farming households to adopt CSA technologies. The result shown in table 16 indicated that access to the phone has a statistically significance ($P<0.05$) and positive influence on the adoption of both compost and crop residue. The value of the odd ratio pointed out that as phone access of smallholder rice farming households increases, the probability of adopting compost and crop residue increases by a factor of 1.954 and 1.9124 respectively. The marginal effect of access to the phone indicated that keeping the other variables constant, as smallholder rice farming households' access to phone increases, the likelihood of adopting compost and crop residue increases by 11.4% and 11.1% respectively. This finding confirms that farmers who owned a mobile phone are more likely to adopt CSA technologies. These results contradicted with the earlier study finding of Donkoh, Azumah, & Awuni (2019) that confirms farmers who owned mobile phones had less chance of adopting agricultural technologies as a result of their poor operating skills.

Age of Rice Farming Household Head

The age of the household is one of the key factors influencing rice farming households to adopt CSA technologies. The result shown in table 16 revealed that the age of household heads has a negative influence on the adoption of soil bund for water management, compost, and crop residue at 1%, 5%, and 5% significant levels respectively. The value of the odds ratio indicates that as the age of household heads increases by one year, the probability of the adoption of soil bund, compost, and crop residue decrease by a factor of 0.9698, 0.9683, and 0.9694 respectively compared to younger household heads. The result of the marginal effect indicated that keeping other variables constant, as the age of household head increases by one year, the likelihood of practicing soil bund, compost, and crop residue also decreases by 0.56%, 0.54%, and 0.54%. This implies that young rice farmers are more eager to recognize new CSA technologies that enhance their rice profitability along with alleviating environmental problems than aged farmers. This result agreed with the finding of earlier empirical studies by Anteneh, Ayele, & Adane (2021), Tran et al., (2019), and Zegeye & Fikire (2021).

Family Size

The family size of rice farming households is one of necessary the factors that influence households' decision to adopt CSA technologies (soil bund). The result revealed that the family size of rice-producing farmers has a positive influence on the adoption of soil bunds with a statistically significant level (0.05). The odd ratio of the family size indicated that as the number of family members increases, the adoption of soil bunds increases by a factor of 1.1749. The result of the marginal effect showed that keeping the other variables constant, as the family size of rice farming households increases by one person, the likelihood of practicing soil bund increases by 2.94%. This implies that large family sizes are more likely to adopt CSA technologies (soil bund) since labor is the main input for rice crop production. This is consistent with previous studies of Etim & Ndaeyo (2020) and Zegeye & Fikire (2021) who revealed that big family members are more ready to adopt CSA technologies. In line with these, the study of Tran et al., (2019) show that large family size is more eager to accept labor demanding new climate-smart agricultural technologies that enhance the profitability of rice production.

Education Status of Household Head

Household heads' education level was found to be statistically significant ($P<0.1$) and positively affect the adoption of compost. The value of the odd ratio of education level indicated that as the educational level of the head increase, the probability of adopting compost increases by a factor of 1.6556 compared to household heads with no formal education. The marginal effect value signified that keeping other variables constant, as the educational status of household head increase, the probability of adopting compost increases by 8.6% compared to non-educated household heads. The result implies that better exposure to education makes household heads to know and understand in order to be more flexible to adopt new CSA technologies including compost. This result is consistent with Victor, Melusi, & Ajuruchukwu, (2019), who revealed that educated farming households would easily adopt modern agricultural technologies. Correspondingly, the study finding of Donkoh, Azumah, & Awuni (2019), Njuguna (2020), Ha & Bac (2021),) Dung (2020), and Etim & Ndaeyo (2020) revealed that an increase in the educational status of rice farmers also enhances their understanding about CSA technologies adoption into farmlands.

Number of Livestock (TLU)

The number of livestock is one important factor influencing smallholder rice-producing farmers' willingness to adopt CSA technologies. As indicated in table 16, the number of livestock was found to be statistically significant ($P<0.1$) and positively affect the adoption of compost. On the contrary, it has a negative effect on the willingness of adopting crop residue with a statistically significant level ($P<0.01$). The odd ratio of the number of livestock (TLU) showed that as the number of livestock increases by one unit, the likelihood of adopting compost and crop residue increase and as a such decrease by a factor of 1.1405 and 0.8224 respectively. The result of the odds ratio signifies that holding other variables constant, as the number of livestock (TLU) increases by one unit, the chance of adopting compost increases by 2.19%. This finding implies that households that herd large numbers of livestock are more likely to adopt CSA technologies (compost) because they are the supplier of manure and means of revenue, similar to an empirical study by Zegeye & Fikire (2021) and Dube (2016). Conversely, as the number of livestock (TLU) increases by one unit, the probability of adopting crop residue is decreased by 3.4%. This implies that, since crop residue is the main feed source of livestock in the rural area of Ethiopia, there might not be crop residue left on the paddy field for the purpose of soil improvement (Gilo & Berta, 2016).

Road Distance

Road distance was found to be statistically significant ($P<0.01$) and has a positive effect on the adoption of soil bund, but negatively correlated with the adoption of compost. The odd ratio value indicated that as the road distance increases, the probability of practicing soil bund increases by a factor of 1.0496, but the probability of compost decreases by a factor of 0.9356. The marginal effect value of road distance indicated that keeping other variables constant, as the road distance increase by one unit, the likelihood of adopting soil bund increases by 0.88%.

Unfortunately, the finding of this study contradicts the research expectation. Based on information obtained from key informants (2022) rice farming households far from the main road were upland residents namely in Dilmo and Abagunda Sendega kebeles. As a result, farmers keep rainwater by constructing soil bunds to obtain better rice grain yield than in waterlogged areas. The study finding by Batiwaritu & Mvena (2009) shows that there is a positive association between farmland distance and soil bund adoption. Zegeye & Fikire (2021) argues that distance to the road increases farmers' will adopt nearby available CSA technologies.

On the other hand, keeping other variables constant, as the road distance increase by one unit, the likelihood of adopting compost decrease by 1.1%. This finding confirms that rice farming households who settle close to the main road are more eager to adopt CSA technologies (compost) because they can easily access them. This result is consistent with the study finding of Nguru et.al., (2021) and Folefack (2015) revealed that farmers close to the main road are more likely to adopt compost or organic manure. Similarly, the finding of Zegeye & Fikire (2021) study showed that farmers who dwell distant from the all-weather road are reluctant to accept farm technologies since they have less access to information.

Household Income

Household income is one of the key factors influencing the willingness of smallholder rice farming households to adopt CSA technologies. The income of smallholder rice farming households was found to have a positive effect on the adoption of soil bund, compost, and crop residue at a statistically significant level ($P<0.01$), ($P<0.1$), and ($P<0.05$) respectively. The odd ratio value indicated that an increase in income of smallholder rice farming households by one birr results in an increase in the probability of constructing soil bunds; using compost and crop residue by factors of 196.038, 9.4182, and 33.1654 respectively. The marginal effect pointed out that keeping the other variables constant, as the income of rice farming household increase by 1 birr, the likelihood of adopting soil bund, compost, and crop residue increases by 96%, 37%, and 60% respectively. This finding implies that smallholder rice farming households who earn higher farm income be likely to spend on CSA technologies. The result is consistent with Lungu (2019) and Etim & Ndaeyo (2020). Similarly, the study finding of Njuguna (2020) also revealed that an increase in income is a guarantee for the next cycle of better yields and high incomes.

Table 16: Binary logistic regression model result on the determinants of rice farmers' adoption of CSA technologies

Explanatory variables	Crop residue				Compost/ organic manure				Soil bund			
	Coefficient	**Robust Std. Err.**	**Odds ratio**	**dy/dx**	**Coefficient**	**Robust Std. Err.**	**Odds ratio**	**dy/dx**	**Coefficient**	**Robust Std. Err.**	**Odds ratio**	**dy/dx**
Sex (male)	-0.8606**	0.3365	0.4229	-0.1518	-0.0878	0.3169	0.916	-0.0146	0.8837*	0.2982	2.4198	0.1678
Extension Access (yes)	1.225*	0.3519	3.4043	0.2022	0.4445	0.3429	1.5597	0.0738	-0.4262	0.3244	0.653	-0.0753
Media Access (Yes)	-0.253	0.2697	0.7765	-0.0439	0.0067	0.2742	1.0067	0.0011	-0.0417	0.2597	0.9591	-0.0076
Phone Access (yes)	0.6484**	0.3202	1.9124	0.1115	0.6699**	0.3043	1.954	0.1137	-0.3583	0.304	0.6988	-0.0635
Credit Access (yes)	0.4597	0.3044	1.5837	0.0789	0.0962	0.3271	1.101	0.016	-0.4077	0.3079	0.6652	-0.0727
Observe Unpredicted Climate change (yes)	-0.0028	0.316	0.9972	-0.0005	0.3412	0.3041	1.4067	0.05656	0.2423	0.307	1.2742	0.0449
Education (educated)	0.2712	0.2665	1.3115	0.0474	0.5042***	0.2779	1.6556	0.0863	-0.1361	0.2786	0.8727	-0.0246
Age	-0.0311**	0.013	0.9694	-0.0054	-0.0322**	0.0135	0.9683	-0.0054	-0.0307*	0.0117	0.9698	-0.0056
Family size	0.0299	0.0914	1.0304	0.0052	-0.0118	0.0928	0.9882	-0.002	0.1612**	0.0771	1.1749	0.0294
Land size	0.9756	0.6685	2.6527	0.1682	0.1042	0.5828	1.1098	0.0173	-0.5095	0.4982	0.6008	-0.0929
Livestock (TLU)	-0.1956*	0.0724	0.8224	-0.0337	0.1315***	0.0729	1.1405	0.0219	-0.088	0.0713	0.9157	-0.016
Road Distance	-0.0135	0.0143	0.9866	-0.0023	-0.0666*	0.017	0.9356	-0.0111	0.0484*	0.0144	1.0496	0.0088
Log of income	3.5015**	1.6361	33.1654	0.6035	2.2426***	1.3416	9.4182	0.3729	5.2783*	1.274	196.038	0.9618
_cons	-18.6294**	8.086	8.12e-09		-12.3159***	6.5868	4.48e-06		-26.9883 *	6.2103	1.90e-12	
	Number of obs = 376 Wald chi2(13) = 73.28 Prob > chi2 = 0.0000 Log pseudolikelihood = -191.4336 Pseudo R2 = 0.2220				Number of obs = 376 Wald chi2(13) = 88.14 Prob > chi2 = 0.0000 Log pseudolikelihood = -186.6929 Pseudo R2 = 0.2510				Number of obs = 376 Wald chi2(13) = 88.96 Prob > chi2 = 0.0000 Log pseudolikelihood = -203.0287 Pseudo R2 = 0.2152			

Note: * P<0.01, **P<0.05 and ***P<0.1

Source: Own survey (2022)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Rice is a nutritional staple food grown under waterlogged areas that plays a vital role to address the challenges of food insecurity. The productivity and profitability of rice cultivation are improved by implementing climate-smart agricultural technologies. Thus, the main purpose of this study was to investigate factors influencing farmers' adoption and profitability of climate-smart agricultural technologies in the smallholder rice farming household of Fogera Woreda in the Amhara region, Ethiopia.

Climate-smart agricultural technologies namely maintaining crop residue, use of organic manure or compost, and water management through constructing soil bunds were considered in this study. Out of 376 sampled rice farming households, 36.2% of respondents were adopters of crop residue while the remaining 63.8% of them were non-adopters. Of those total respondents, 37.8% of them adopt compost while 62.2% did not adopt it. Similarly, 55.1% of the total 376 respondents adopt soil bunds, and the remaining 44.9% did not construct soil bunds. There was a significant difference in sex, age, marital status, family size, educational level, land ownership, farmland size, livestock size, and total farm income of rice farming households between non-adopter and adopters.

The profitability of CSA technologies in rice farming was estimated by gross margin and net profit analysis. The finding showed that CSA technology adopters of crop residue, compost, and soil bund earned the highest net return of 142432.53 birr/ha, 142207.92birr/ha, and 135003.20 birr/ha respectively than non-adopters. The gross margin of the adopters of crop residue, compost, and soil bund was 167100.77 birr/ha, 166268.68 birr/ha, and 157353.00 birr/ha. This study result revealed that CSA technology adopters earned more gross margin and net profit than non-adopters.

In this study, binary logistic regression was employed to estimate the influence of demographic and social, climatic and information, institutional and economic factors on smallholder rice farming households' decision to adopt CSA technologies.

Access to extension services, phone access, and farm income positively and statistically significantly influence smallholder rice farming households' decision to adopt crop residue. Whereas, sex, age, and the number of livestock herds negatively and statistically significantly influence crop residue retention/maintenance. Access to phone, education, number of livestock herds, and income positively and statistically significantly influence smallholder rice farming households' decision to use compost/organic manure. Whereas, age and road distance negatively and statistically significantly influence compost adoption. The construction of soil bunds for water management is positively and statistically significantly influenced by sex, family size, road distance, and income. While age also negatively and statistically significantly influence the adoption of soil bund.

5.2. Recommendations

The following recommendations were suggested by the researcher based on the study findings of factors influencing farmers' adoption and profitability of climate-smart agricultural technologies in smallholder rice farming households of Fogera Woreda, Amhara Region.

- The CSA technology adopters earned more gross margin and net profit than non-adopters. Thus, government and other stakeholders should strengthen agricultural extension services regarding climate-resilient rice production and adoption of CSA technologies for rice farmers by identifying their skill gap.
- Education increases the awareness of smallholder rice farming households on CSA technologies which will enhance their rice productivity. As a result, efforts to enhance the educational status of smallholder rice farming household has huge benefits for boosting rice productivity as well as the national economy at large.
- Besides, the effectiveness of CSA technologies is also enhanced by accessing information through communication technologies like mobile phones which broadens the awareness of rice farmers. So, appropriate mobile applications that enhance the

awareness of rice farmers' adoption of CSA technologies should be released by the concerned body. The smallholder rice farming household should be aware of the use of mobile phone devices.

- Distance from the main road to the paddy field influences the smallholder rice farming households' decision to adopt CSA technologies. Government and various actors should improve the infrastructural accessibility of the area for better rice productivity in the community.
- Farm income generated from livestock rearing and crop production also determines the smallholder rice farming households' decision to adopt CSA technologies. As a result, proper policy measure that improves farmers' economic condition is required to enhance their capacity for CSA adoption.
- Rice farming households that herd small numbers of livestock are less likely to adopt compost as a CSA technology. As a result, government and various actors should take measures that improve the productivity of livestock assets of the smallholder farmers.
- There are plenty of CSA technologies that enhance the crop productivity of farmers but only 3 of them have been investigated in this research by using cross-sectional data. Estimating the profitability and investigating factors that influence the adoption of numerous CSA technologies in smallholder farmers will be the theme for further study on a wider geographic area using time series data. In addition, changing the methodological approach i.e. using two stages least square model will be another area of theme for further research.

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APPENDIX I

ADDIS ABABA UNIVERSITY

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Questionnaire for rice farming household

Dear respondent,

My name is Belachew Getnet a master's degree student at Addis Ababa University in the environment and sustainable development. At this time, I am conducting a research entitled "Factors influencing farmers' choice and profitability of climate-smart agricultural technologies in rice farming household: a case study of Fogera Woreda of Amhara region, Ethiopia". Thus, information obtained from you will be used for academic purposes only and your identity will remain secured and confidential.

Your valuable and honest response is critical for the success of this study. As a result, the researcher kindly requested you provide your genuine response.

General Information

Questionnaire Code __________________

Enumerator name____________________ Date __________________

Name of Kebele:

1= Shina

2= Shaga

3= Kidist Hana

4= Abagunda Sendega

5= Dilmo

Part I: Socioeconomic background information of rice farming household

1.1. Sex of household head

1= Male

2= Female

1.2. Age of household head in years __________

1.3. Family size of rice farming household

Sex	**Number of family members**			
	Below 15 years	From 15- 64 years	Above 64 years	Total
Male				
Female				
Total				

1.4. The educational level of the household head

1= None educated or illiterate

2= Primary (From grades 1 - 8)

3= Secondary and preparatory (From grade 9-12)

4= Technical and vocational

5= Degree and above

1.5. Marital status of rice farming household head

1= Single

2= Married

3= Divorced

4= Widowed

1.6. Do you have your own land?

1= Yes

2= No

1.7. Size of owned land and land use system of the household

S.No	Land use system	Size of land in *timad*	Remark
1	Cultivated land		
2	Grazing land		
3	Plantation		
4	If other Specify ___________		
5	Total land		

1.8. The amount of crop produced in the cultivated area of land

S.No	Cultivated crop type	The area of land cultivated (in *Timad*) and The amount of crop produced													
		Land with own holding right		Rented in land		Shared in land		Rented out land		Shared out land		Total Area in *Timad*	Total Farm income		
		Area of land	**Produced in kg**	**Area of land**	**Produced in kg**	**Area of land**	**Produced in kg**	**Area of land**	**Produced in kg**	**Area of land**	**Produced in kg**		production in kg	Sold in kg	Price per kg
1	Rice														
2	Teff														
3	Maize														
4	Vegetable														
5	Others (specify) ________														
Total															
Total production income in birr															

1.9. The total number of livestock reared by the rice farming household

S.No	Type of livestock	Total number of livestock owned	Estimated current selling price (in birr)	Remark
1	Cattles			
2	Goat			
3	Sheep			
4	Donkey			
5	Horse/ mule			
6	Chicken			
7	Others (specify) ____________			
Total number of livestock (in total livestock unit)				

1.10. Total farm income of rice farming household in birr____________

1.11. Apart from farm income, do you have additional income from the off-farm?

1= Yes

2= No

1.12. If your answer is yes; the total amount and source of income from off-farm activity

S.No	**Source of income**	**Annual amount of income in birr**
1	Domestic or foreign remittance	
2	Salary	
3	Handcraft	
4	Safety net	
5	If others specify___________	
Total		

Part II: Adoption of CSA Technologies

2.1 Choose climate-smart agriculture (CSA) technologies you have adopted in the paddy field? (Multiple answer is possible)

1= Not adopted any CSA technologies

2= Maintain crop residue (leaving at least 1/3 of the crop residue on the paddy field)

3= Use of compost or organic manure in the paddy field

4= Constructing soil bund in your paddy field

2.2 The total area of paddy field that you have adopted CSA technologies are __________ *Timad*.

2.3 What is the reason to adopt CSA technologies in your paddy field?

____

____

____

2.4 What is the limiting factor for not adopting CSA technologies in the paddy field?

____

____

____

Part III: Institutional, climate, and information factors

3.1. Do you have access to an extension service on Climate smart agricultural technologies to adopt in the rice field?

1= Yes

2= No

3.2. If your answer is yes; who delivers extension service for you?

1= Government

2= NGO

3= Other farmers

4= Specify if others____________

3.3. How many times do you meet with extension agents per year__________________

3.4. Distance in kilometers/meters from the main road to your paddy field for transporting your products and inputs is______________________

3.5. Do you have broadcasting media access?

1= Yes

2= No

3.6. If your answer is yes; which one of the following media do you access?

1= Radio

2= Television

3= Both radio and television

4= Specify if others___________________

3.7. Do you have access to communication technologies like a mobile phone?

1= Yes

2= No

3.8. Do you have a chance to access credit?

1= Yes

2= No

3.9. If your answer is yes; who gives credit to you?

1= Bank

2= Credit and saving institution

3= Local money lender

4= Specify if others ___________________

3.10. Have you observed unpredictable climate change in your district?

1= Yes

2= No

PART IV: Profitability of CSA in rice farming household

4.1. How many parcels or plots of rice farm land do you have? _______________

4.2. What is the total size of your parcels or plots of land in *Timad*?

____

4.3. The total production cost of rice farming household for their total rice farmland/paddy field

<table>
<tr><th>S. No</th><th colspan="2">Type of costs</th><th>Unit</th><th>Unit price in birr</th><th>Quantity needed</th><th>Total Cost in Birr</th></tr>
<tr><td>1</td><td colspan="2">Organic Manure/ compost (Prepared by household labor)</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td colspan="2">Fertilizer</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td colspan="2">land (estimated rent value)</td><td>Hectare or (Timad)</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td colspan="2">Seeds</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td colspan="2">Herbicide</td><td>Liter</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">6</td><td rowspan="3">Animal power cost</td><td>Plowing</td><td>Ox/day</td><td></td><td></td><td></td></tr>
<tr><td>Trashing</td><td>Ox/day</td><td></td><td></td><td></td></tr>
<tr><td>Transporting yield</td><td>Donkey/day</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">7</td><td rowspan="5">Labor cost</td><td>Water management</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>Land preparation including crop residue maintenance</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>Weeding</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>Harvesting</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>Trashing and winnowing</td><td>Man/day</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td colspan="2">Other costs</td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td colspan="4">Overall cost</td><td></td><td></td></tr>
</table>

4.4. Total yield from rice production by adopting CSA technologies

<table>
<tr><th>S. No</th><th colspan="2">Source of revenue</th><th>Unit</th><th>Unit price in birr</th><th>The total quantity of yield</th><th>Total price in Birr</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Paddy yield</td><td>Grain yield</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>Husk yield</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td colspan="2">Straw yield</td><td>Shekim</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td colspan="2">Other yields</td><td>Kg</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td colspan="5">Overall total yield</td><td></td></tr>
</table>

Thank you!

APPENDIX II

Multicollinearity test for continuous variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.522	.763		-3.308	.001		
	Age of household head	-.005	.002	-.140	-2.893	.004	.901	1.110
	Total Family size of the household	.022	.015	.084	1.463	.144	.641	1.559
	the area size of total owned land	-.017	.093	-.015	-.188	.851	.338	2.960
	number of livestock in the total livestock unit	.003	.011	.019	.255	.799	.387	2.584
	Distance in kilometers from the main road to the paddy field	.008	.003	.137	2.913	.004	.948	1.054
	Log income	.585	.154	.349	3.804	.000	.251	3.986

a. Dependent Variable: SoilBund

APPENDIX III

Multicollinearity test for categorical variables using Pearson Correlation

		Sex	extension service access	broadcasting media access	access to mobile phone	access to credit	observed unpredictable climate	Education
Sex	Pearson Correlation	1	.027	-.014	.108*	-.016	.052	.078
	Sig. (2-tailed)		.596	.793	.036	.758	.319	.132
	N	376	376	376	376	376	376	376
access to an extension service	Pearson Correlation	.027	1	.020	.064	.056	.106*	.302**
	Sig. (2-tailed)	.596		.695	.215	.278	.041	.000
	N	376	376	376	376	376	376	376
broadcasting media access	Pearson Correlation	-.014	.020	1	-.001	.018	-.045	-.052
	Sig. (2-tailed)	.793	.695		.977	.730	.381	.312
	N	376	376	376	376	376	376	376
access to communication technologies like a mobile phone	Pearson Correlation	.108*	.064	-.001	1	-.119*	.226**	.100
	Sig. (2-tailed)	.036	.215	.977		.021	.000	.053
	N	376	376	376	376	376	376	376
access to credit	Pearson Correlation	-.016	.056	.018	-.119*	1	-.019	.091
	Sig. (2-tailed)	.758	.278	.730	.021		.711	.077
	N	376	376	376	376	376	376	376
observed unpredictable climate change	Pearson Correlation	.052	.106*	-.045	.226**	-.019	1	.107*
	Sig. (2-tailed)	.319	.041	.381	.000	.711		.037
	N	376	376	376	376	376	376	376
Education	Pearson Correlation	.078	.302**	-.052	.100	.091	.107*	1
	Sig. (2-tailed)	.132	.000	.312	.053	.077	.037	
	N	376	376	376	376	376	376	376

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).