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SCHOOL OF POST-GRADUATE STUDIES

DETERMINANTS OF AGRICULTURAL INPUT TECHNOLOGIES ADOPTION BY SMALLHOLDER FARMERS IN RURAL AMHARA REGIONAL STATE, ETHIOPIA.

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ADDIS ABABA, ETHIOPIA

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A Thesis Submitted to The School of Commerce of Addis Ababa University in Partial Fulfillment of the Requirements for The Degree of MASTERS OF SCIENCE IN DEVELOPMENT ECONOMICS

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DECLARATION

I, the undersigned, hereby state that this thesis, titled “Determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia," is entirely my own work and has not been submitted for consideration for any degree or diploma from this university or any other. Each and every source of information used in the thesis has been properly acknowledged.

Declared By: Name: Senawit Tegegn

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Place of Submission: School of Commerce, AAU

Addis Ababa, Ethiopia

STATEMENT OF CERTIFICATION

This is to certify that Senawit Tegegn's thesis, "Determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia," which he completed under my supervision and submitted as partial fulfillment of the requirements for the degree of Master of Science in Development Economics at the School of Commerce of Addis Ababa University, is an authentic work. To the best of our knowledge, no other university has received a thesis with the same central theme for the award of a degree or diploma.

Sisay Debebe (Ph.D.)	______________	______________	Addis Ababa, Ethiopia
Advisor	Signature	Date	Place

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ABBREVIATIONS AND ACCRONYMS

AgSS	Annual Agricultural sample survey
AgSS-EA	AgSS Enumeration Area
BMGF	Bill and Melinda Group Foundation
EA	Enumeration Area
CR	Crop Rotation
CSA	Central Statistical Agency
ESS	Ethiopian Socio-Economic survey
EPCC	Ethiopian panel on climate change
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
HH	Household
IAASTD	International Assessment of Agricultural Science Technology for Development.
ISA	Integrated Survey on Agriculture
LSMS	Living Standard Measurement Study
LSMS-ISA	Living Standard Measurement Study Integrated Survey on Agriculture
MOA	Ministry of Agriculture
MVP	Multivariate probit
NGO	Non-government organization
SRS	Simple Random Sampling
UNDP	United Nations Development Program
USA	United States of America

ABSTRACT

The adoption of agricultural technology is an important route for raising agricultural productivity, and thereby for increasing food security status; over the past several years, a great deal of technologies has been developed. However, small-scale farmers only embraced a small portion of these technologies. So it is essential to comprehend and to be informed the obstacles to adoption of modern agricultural technologies quite crucial to develop and distribute practical technologies to farmers. Despite countrywide initiatives to encourage adoption, the rates have generally been minimal. This study investigates the determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia, the study is based on an Ethiopian socio-economic survey of 2018/19 and a sample of 487 farm households is considered. Descriptive and econometric analysis tools were used. The results show that about 15.61%, 88.09%, 60.99%, 40.66%, and 32.44% of sample households adopted improved seed, crop rotation, chemical fertilizer, pesticide, and herbicide respectively. Technologies were complementary and Smallholder farmers were more likely to succeed than fail in jointly adopting agricultural technologies. The paper uses a multivariate probit model to assess the factors affecting the adoption decision of agricultural technology. The result shows that farmers with more educational level, extension service, sex, age, oxen power, soil quality, and access to irrigation, erosion, credit access, advisory service, and distance from the market are more likely to adopt new or improved agricultural technology. Accordingly, the study recommends the need of policies and interventions on adoption of agricultural technology should pay attention and move along with those variables significantly influencing adoption of agricultural technology and other concerned parties should emphasize the strengthening of the institutional support network.

Keywords: *Agriculture, technology adoption, extent, multivariate probit, Amhara, Ethiopia.*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Agriculture is the primary driver of economic activity in developing countries, contributing significantly to Gross Domestic Product (GDP), exports, and jobs. Agriculture also plays an essential part in the global economy. Agriculture, service, and industrial sectors contributed 45, 44, and 11 percent of GDP over the last five years (2008/09-2012/13), respectively, (UNDP Ethiopia, 2018). Farmers in underdeveloped nations depend on farm income and experience a hand-to-mouth way of life. This is a result of inadequate technological advancement, high population growth, and low livestock yields (FAO, 2016).

Agriculture is a key part of the Ethiopian economy. With a higher contribution to the gross domestic product, foreign exchange earnings, and employment. Agriculture is supposed to remain a sector that plays a key role in encouraging the overall economic development of the country. This would be understood if and only if the government and other relevant entities, including farmers, made unwavering efforts to increase agricultural production and productivity. (CSA, 2016).

Agriculture is the backbone of Ethiopia's economy. It employs over 85% of the working population (MOA, 2017), supports the livelihoods of millions of people (Njeru et al., 2016), and contributes 43% of the national GDP (EPCC, 2015). However, using less expensive technology results in low output and income, which restricts farmers' ability to produce. (Johnston & Mellor, 2016). But one of the biggest challenges the country faces is attaining higher and more consistent agricultural productivity growth. (Spielman et al., 2010; Ahmed et al, 2014).

One strategy to boost agricultural productivity is to expand the use of farming technologies, which have been proven to have a major influence on income, food security, and poverty alleviation. (Asfaw et.al., 2011; Alene et al., 2009; Kassie et al., 2011). Adoption of technology can also enhance nutritional status (Kumar and Quisumbing, 2010); lower food prices (Karanja et al., 2003) and reduce the risk of crop failure (Hagos et al., 2012). However, agricultural technology adoption rates are still extremely low, particularly in Africa. (Spielman et al., 2010). Additionally, there is controversy regarding the technology best suited for the small agricultural sector. (Priscilla et al., 2014). While some believe low external input approaches are most fitting for African smallholders (IAASTD, 2009), others such as Pingali (2007) promote the necessity of increasing contributions.

Due to a lack of food production, food insecurity, and high poverty, the nation is experiencing serious development problems. 26.3% of the population is deemed poor under the $1 per day global poverty level, and 80.7% by the $2 per day criteria (National Planning Commission, 2017). Since then, the country has been using a number of extensive measures to promote the implementation of better contemporary agricultural inputs (Tefera et al., 2016).

Despite having a direct impact on raising yield and income production as well as nutrition level, agricultural technology adoption is still quite low in the nation. For instance, the adoption rates of fertilizers, better seed, herbicides, and irrigation for the 2014–2015 agricultural season were 55.15, 8.78, 22.35, and 6.25 percent’s respectively (Shita et al., 2018).

This study is conducted in Amhara regional sate of Ethiopia. In the region agriculture is the primary economic sector, in which nearly 84% of the population lives in rural areas. The most common agricultural activities practiced in the region are crop production, plantation, animal husbandry, forestry and logging, and fishing. The farmer has to increase agricultural productivity based on the adoption of modern agricultural technologies more profitably. As it has been clearly explained above, there are numerous studies, reports, and finding on different aspects of agriculture and the adoption of modern input and technologies. However, the determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state are not well addressed in the region. Therefore, the study aimed to assess the Determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia.

1.2. Statement of the problem

Agriculture is the backbone of the economy and provides a living for the majority of people in developing nations, such as Ethiopia. Hence real and sustainable development is impossible without putting agricultural output development so agriculture plays the dominant role in the Ethiopian economy. This is primarily attributed to the ineffective use of modern inputs like fertilizers, improved seeds, and extension services, which partially explains the industry's lower productivity. In addition to this, the farmers' internal inefficiency in using the available agricultural resources, including land and labor, is also to blame (Tenaye, 2020).

Farmers in developing nations depend on farm revenue, distinguished by poor revenue and a lack of food supplies. This is a result of inadequate technological advancement, high population growth, and low livestock yield (Tadele, 2021).

Due to several institutional, economic, and physical constraints, farmers in Ethiopia still use very few modern agricultural inputs, even though the overall usage of such inputs has been increasing. A decision element to improve agricultural input utilization. To increase agronomic output and production, administration ought to put a strong emphasis on avoiding obstacles that are outside the cooperatives' capacity for financing. In general, the intensification of better agricultural technology will be necessary to achieve future advances in agricultural production and productivity (Cafer & Rikoon, 2018).

The Ethiopian economy's most significant industry is still agriculture. Regardless of its significance, the nation's agriculture is characterized by low production and a system of land-fragmented farming. There is a gap between the actual and prospective yield levels of numerous crops in Ethiopia (Tessema, 2011).
This highlights the need for additional efforts to ensure that farmers understand the role that agricultural input plays in boosting agricultural productivity and to ensure improved input adoption at the farm level and the fast increase of agricultural production can be realized by raising labor and land productivity through new technologies input (Tefera et al., 2016). However, production and productivity have long been extremely unsatisfactory due to various factors; Ethiopian farmers are currently utilizing relatively little modern agricultural inputs. So It will be challenging for the government to achieve optimum agricultural growth if farmers continue to utilize poor-yielding types (Beyene et al., 2020).
In Ethiopia, different studies have been conducted on the determinants of adoption of agricultural technology; for example, (Admassie & Ayele, 2010, Kassie et al., 2010; Hundie & Mulugeta, 2012; Hailu et al., 2014; Asfaw et al., 2012; Amare, 2018; Sebsibie et al., 2015; Wudu, 2017; Worku, 2019; Gebru, 2016; Natnael, 2019; Feyisa, 2020; Massresha et al., 2021; Ayenew et al., 2020; Tamirat & Abafita, 2021). They found that agricultural technology adoption decisions are influenced by factors of demographic, socioeconomic, institutional and plot characteristics. However, many of the aforementioned studies show the determinants of single agricultural technology adoption decisions. Hence, none of them showed farmers' decision to adopt multiple agricultural technologies and extent of the technologies package. Thus, this paper investigates the determinants of adoption decisions of multiple agricultural technologies by considering adopters of at least one and more

technologies in any of one of the crop land it is vital to know how farmers Adoption of specific technologies depends on other technological choices on a similar farm. Moreover, many of the studies conducted are using a few explanatory variables and covers a small sample and area coverage. However, this study includes several explanatory variables and covers a large sample than the aforementioned studies.

To improve the livelihood of farming households, the application of modern agricultural technologies was taken as a measure throughout the region. Although there is a great focus on the application of agricultural technologies, the adoption rate of the Amhara region is quite low in the region, even as compared to Oromia and Southern nation nationalities and people's regions of Ethiopia and the use is still lower than the recommended rates (Tefera et al., 2016; Zegeye, 2021). Therefore, it is meaningful to investigate the factors of adopting agricultural technologies in the Amhara region. However, there are no enough studies conducted on the factors of adopting agricultural technologies in the region. Thus, this study investigates the Determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia.

1.3. Research Question

I. What is the status and extent of modern agricultural technologies in the study area?

II. What are the determinants affecting the adoption of modern agricultural technologies in the study area?

III. What are the determinants of the relationship between different agricultural input technologies?

1.4. Objective of the study

1.4.1. General Objective of the Study

The overall goal of this research is to examine the determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia.

1.4.2. Specific Objectives of the Study

I. To describe the status and extent of modern agricultural technologies in the study area.

II. To determine the determinants affecting the adoption of modern agricultural technologies in the rural Amhara region of Ethiopia.

III. To identify the inter-dependence of agricultural input technologies adopted by smallholder farmers.

1.5. Significant of the study

The structure of the Ethiopian economy, as we know, is highly dominated by agriculture: so the suggested study provides significance for farmers, the government, and individuals who are engaged in agriculture. Hence it serves as a source of information for other researchers who wants to conduct further study regarding agriculture problem and other related studies. The study can also provide certain pieces of proof to policymakers that could possibly be used in their decision-making process, in addition to initiating more research and adding to the body of knowledge already available in the field

1.6. Scope and Limitation of the Study

This study mainly focused on identifying and analysing the determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia. It used the 2018/2019 Ethiopian Socioeconomic Survey (ESS4) data to achieve the objectives. The sole region included in the investigation is Amhara, which can have distinct socioeconomic and agro-climatic characteristics compared to other regions of the nation. Therefore, it might be challenging to draw conclusions about the other parts of the country without additional research. However; the separate analyses of different region of the country was gives a clear picture of the farming sector in the area that couldn't touch in this particular study. This is merely due to the limitation of time and other resources. On the other hand, the study has faced some challenges like limited empirical and theoretical facts about the issue in the given area.

1.7. Organization of the Study

The study is structured as follows. Chapter 1 includes background of the study, Statement of the problem, Research Question, Objective of the study, Significant of the study, Scope and Limitation of the Study, Chapter 2 provides a concise summary of substantial literature reviews, theoretical, and conceptual framework is briefly presented. in Chapter 3, which includes, the description of the study area, data source, type, and method of collection, Method of data analysis, and econometrics model are discussed, and the general methodology of this research. The result and discussion were discussed in Chapter 4. Finally, Chapter 5 summarizes the work completed and the outcomes received. Conclusion and recommendations were also presented.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter comprises a literature review that is relevant to the research topic, and includes the theoretical literature on the determinant of modern agricultural technology's adoption among smallholder farmers; moreover, the empirical literature on determinants of modern agricultural input adoption and conceptual framework also made for the study. The literature review aims to reveal the knowledge gaps which the study sought to fill in.

2.1. THEORETICAL REVIEW

2.1.1. Definition of Technology Adoption

Adoption: is a subjective process that describes the stages one goes through from first learning about a thing to ultimately accepting it (Rogers, 1962). The amount to which a new technology is employed in long-run equilibrium when the farmer has a comprehensive understanding of the new technology is described as adoption at the farmer level (Ogada et al., 2014). This means that the aggregate level of certain new technologies within a given geographic region or population is used to estimate aggregate adoption (Kinyangi, 2014). And Rate of adoption is described as the rate at which individuals accept a new technology. The amount of time necessary for a specific percentage of a social system's members to accept an innovation is commonly used to calculate the rate. The rate of adoption determined by an individual is the adopter category. In comparison to late adopters, a person who accepts a new idea early typically needs a shorter adapting period. (Iftakhar, 2016).

Technologies: refers to how to cultivate a crop successfully, This success can be obtained by knowing how to apply improved seed, and fertilizer, control pests, and take care of the plant for its healthy and good growth, and also what crop varieties and what kinds of fertilizers are suitable for the soil (Barrett & Rose, 2022).

Technology choice: The idea of technology choice can be summed up as the idea that there are frequently a variety of alternative technological means available that are suitable for achieving primary goals within a given field and that the number of alternatives in the variety may be gradually increased over time by conscious human effort. Alternative technological solutions that are equally suitable for achieving some core goals may not be equally suitable for achieving other, secondary goals. An important component of social, economic, and environmental policy is the thoughtful choice of technological methods, taking into account both primary and secondary aims, as well as long-term attempts to increase the variety of accessible alternatives (Tite & Sillar, 2000).

2.1.2. Categories of Adopter

Rogers suggests a total of five categories of adopters to standardize the usage of adopter categories in diffusion research (Rogers, 1962). Categories of adopters are:

A. Innovators

Aside from having the highest social standing, the most liquid financial resources, the best social skills, and the closest access to scientific resources and other innovators, innovators also have a high level of social willingness to take risks. Their risk tolerance permits them to accept technology that may eventually fail (Rogers, 1962).

B. Early adopters

Among the adopter groups, these people have the most opinion leadership. Early adopters are more socially progressive and have greater social standing, financial liquidity, and advanced education than late adopters. Compared to innovators, they are more covert about the adoptions they choose. To assist them in keeping a dominant position in communication, they employ wise adoption (Rogers, 1962).

C. **Early Majority**

They decide to adhere to a concept after a significantly longer period of time than inventors and early adopters. The early majority has above-average social standing, communicates with early adopters, and rarely holds positions of opinion leadership in a system (Rogers, 1962).

D. Late Majority

They adopt an innovation after the average participant. After most of society has embraced an idea, this person approaches it with a high level of doubt. The late majority is often doubtful of an invention, has little social standing, limited financial liquidity, is in communication with other members of the late majority, and has minimal opinion leadership (Rogers, 1962).

2.1.3 The theoretical literature on agricultural technological change

Technological changes in agriculture have been observed, as well as the impact of technological change, within the context of the dominant model of agricultural development and technological modernization. Technological change may indicate a partial restructuring of production, while agricultural and social restructuring, in general, and determine, more essentially, the specific character of technology itself. Acceptance of the existing organizational structure and emphasis on technical/production innovations determined by the requirements of the market suggests disregard of critical market failure to ensure sufficient employment and an environmentally and socially viable agricultural economy, misplacement of the factors which have led to the international crisis of the agro-food system, and neglect or abandonment of domestic or local productive practices and know-how, without taking into account specific social, natural and cultural characteristics(Marx k,1997).

2.1.4. Problem and policy issues in the agricultural sector

The foundation for the Ethiopian economy is and remains agriculture (World Bank, 2007) the Ethiopian context this refers to; especially the development of those industries must clearly relate to agriculture and referred to as agro-industries. Because of instability in production, agriculture has failed to play the decisive role expect of it (Slavchevska, 2016) The major obstacles to the development of the agriculture sector include:

A. Land degradation

Studies reveal that because of the topography of the land, 40% of cultivable land in Ethiopia is expressed to various levels of soil erosion for the 2014–2015 agricultural seasons (Shita et al., 2018).

B. Variable rainfall

It is a matter of fact that Ethiopian agriculture is heavily dependent on reliable rainfall which may produce surplus only in years in favorable weather and they face a shortage, if there is no favorable rainfall for the 2014–2015 agricultural season (Shita et al., 2018).

C. Land fragmentation

The increased population size of rural Ethiopia in limited total land areas, especially in the high land areas has been the cause of the decline in capital land holding for the 2014–2015 agricultural season (Shita et al., 2018).

D. Lack of fertility

Lack of improved seeds, traditional way of production, and fluctuation of the price of agricultural output are the major challenges of agricultural input. Comparing the growth derive by different sectors in reducing g poverty and encouraging border-based growth additional growth derived by cereals has a large impact on poverty reduction, especially in rural areas. This is because these crops are already large and so can contribute substantially to achieving broad-based agriculture for the 2014–2015 agricultural seasons (Shita et al., 2018)

2.2. Empirical Literature Review

Studies are being done to better understand how farm households and the entire family accept new agricultural innovations, particularly in agricultural technology. Furthermore, the review, which is divided into two sections the first detailing various adoption and production studies in underdeveloped nations and the second concentrating on adoption and productivity studies in Ethiopia.

2.2.1. Adoption and productivity studies in developing countries

Nigerians' decisions to adopt new agricultural technologies are determined by farming families can benefit from things like enhanced seeds, synthetic fertilizers, and plant pesticides. 1395 farm households that are typical of farm households in Nigeria's cross-sectional data are used in the multinomial probit model. The findings indicated that, depending on the type of agricultural technology, farm households' decisions to adopt that technology were influenced by the age and educational level of the head of the farm household, the size of the farm family members, joining an agricultural collaborative, the number of plots, the level of farm household financial status, the size of the plot, the types of soil on the plot, the plots located in a valley or on a gentle slope, and the land (Ousmane & Nafiou, 2019).

Donkoh et al., (2019) as the amount of arable land per person in Ghana continues to decline, it is becoming more and more crucial to use contemporary technology for rice cultivation. To determine the factors that influence the adoption of new agricultural technologies, this study used a multivariate probit model to analyze household data from 543 rice farmers in Ghana's Upper East and Northern region. All the enhanced rice production technologies worked in tandem (i.e. nursery establishment, harrowing, line planting, spacing, urea briquette, irrigation, and bundling). HH size, sex, farm size, sex, experience Education, and age of the farmer are among the socioeconomic factors that are significant, with varying signals among technologies. Membership in farmer-based organizations, access to research services, training, and credit were significant institutional determinants with varying signals across the more advanced technology. Adoption was significantly and variably impacted by location as well. Additionally, the review was amply justified by the enormous influence that demonstration, TV, radio, video, mobile phones, and household extension methods had on the adoption of upgraded technologies.

Ullah et al., (2015) the variables influencing the adoption of organic farming in Peshawar, Pakistan. Binary logistic regressions were used in the study to categorize organic farming into adoption and non-adoption. The purpose of the model was to check the event probability for a categorical response variable with two outcomes. According to the binary logistics study's findings, the adoption of organic farming is significantly impacted by factors that also have a big impact on productivity among farmers. Furthermore, cost, productivity, profitability, compatibility, and efficiency all have a positive and important impact. Therefore, it is clear that switching to organic farming not only boosts the farmer's revenue but also safeguards against environmental degradation by avoiding harmful fertilizers and chemicals.

Ogada et al., (2014) studied models of inorganic fertilizer and improved maize varieties adoption as joint decisions. Controlling for household, plot-level, institutional and other factors, the study found that household adoption decisions on inorganic fertilizer and improved maize varieties were interdependent Other factors identified to impact the adoption of the two technologies were farmer characteristics, plot-level factors, and market issues such as limited access to financing and input markets, as well as production risk factors. As a result, reducing market flaws is a requirement for boosting agricultural technology adoption among smallholders. Farm adoption of technology and initiatives to promote it must also take into account the interdependence of agricultural technologies.

Fadeyi et al., (2022) Small-scale farming has been recognized as being essential for boosting the economy, enhancing food security, and creating jobs. But due to the restricted application of technologies, smallholder agriculture in Africa is characterized by a low level of production. There were 128 research articles in English published between the start of 2000 and the end of 2019 that focused on the variables encouraging small-scale farmers in Africa to adopt new technologies. The bulks were done in Kenya, Uganda, and Malawi, with maize, beans, and rice as the main crops. This review identified 29 factors that were broadly classified into five main categories; farmers' characteristics; farm characteristics; technology characteristics; institutional factors; and finance. Of these, finance, gender of household head, age education, farm size, and extension access are the most prominent factors mentioned.

2.2.2. Adoption and productivity studies in Ethiopia

Gebeyehu, (2016) investigated the effects of implementing contemporary agricultural technologies in Ethiopia, including the use of improved seed, fertilizers, pesticides, and herbicides. The two-stage method used in this work to estimate a production function was used to compute the average and the production risk factors (both variance and skewness) from the production function. The empirical results showed that the use of better seeds, family labor, agricultural funding, and manure had a positive and significant effect on crop yields. On the other hand, parcel size and chemical inputs (pesticide and herbicide) have a negative and considerable impact on crop productivity. These production factors all affect agricultural yield variability and output skewness in distinct ways. For instance, better seeds and chemical inputs have a substantial and positive impact on the downside risk exposure (risk growing), but fertilizers and parcel size have a significant and negative impact on the negative risk exposure (risk reducing).

Mena, (2016) investigated the factors that influence decision-making when adopting conservation intervention strategies. A binary logistic regression model and descriptive statistics with the relevant statistical tests were employed to evaluate the data. Based on the chi-square test results, family size, educational attainment, social standing, location of agricultural land, stable tenure, non-farm income, education, and access to extension and credit services were all positively and significantly correlated with farmers' choice decisions. Age, sex, the size of the farm, the number of farm plots, the grade of the slope, and the type of soil were not significant variables.

Belete et al., (2020) study examines how the implementation of agricultural inputs in the study area is affected by demographic variables like sex, age distribution, marital status, family size, number of oxen, educational level, and farmland size, as well as factors affecting the adoption of modern agricultural inputs like extension contact, price of farm inputs and outputs among others. In order for agricultural extension plans to be effective and for different agricultural practices to be embraced, a partnership between farmers and extension services is crucial.

Workineh et al., (2020)studied The livelihood of rural farm households depends heavily on agricultural productivity and production. The welfare of rural farm families and agricultural productivity are both impacted by agricultural technology. On the welfare of farm households, however, nothing is known about the impact of various technological adoptions. This study looked at how household welfare in Ethiopia was affected by the adoption of better wheat varieties. A semi-structured questionnaire administered to 150 sample farm homes was used to collect cross-sectional data for the study. Models with double hurdles and endogenous switching were used. The findings suggest that factors such as availability to financing, extension visits, soil fertility, plot size, off-farm work, household head's age, distance from the input market, and farm experience have an impact on farm families' decisions to adopt improved wheat varieties and the degree to which they do so. The calculated model also shown that the adoption of enhanced wheat varieties significantly and favorably impacts the welfare of farm households. Accelerated adoption of agricultural technology that enhances output is necessary to enhance the welfare of small-scale farmers.

The empirical literature review above prevails that there is limited work in the area of determinant of modern agricultural technology's adoption. . Moreover, the multivariate probit model is lowly applicable to many studies of the adoption and uses few explanatory variables in the study area. Hence, this study adopted the most widely applicable method of estimating adoption of multiple technology's large explanatory variable and this study adopted the most widely applicable method of estimating adoption, Correlation matrix, MVP, in estimating multiple technologies of agricultural production in Ethiopia and in addition the relevance for the present generation was not significant because of the modern agricultural technology inputs are the requirement of modification which coincides with the time , so this study contribute to the study area by give some implication on factors affecting the adoption of modern agricultural inputs technologies by using one or more technologies on similar farm simultaneously . And as explained above most literature was not studying detail and doesn't deal with all modern agricultural technologies. However, in this study deals about the determinant factors of modern agricultural technologies such as improved seed, chemical fertilizer, pesticide, herbicide, crop rotation (CR). From the literature we can draw the conclusion that the technology in Africa and the rest of the world are not comparable; therefore, the technology available in the rest of the world is different from that in our nation, Ethiopia.

2.2.3. Conceptual Framework of the Study

Different factors affect the adoption of agricultural technology choices. These factors are socioeconomic factors (livestock ownership, Oxen power, annual income, off-farm employment), institutional factors (access to credit, extension service, advisor service, landownership right , distance from market, distance from zonal town) Demographic factors (sex, age, and family size, education), and plot characteristics factors (land size, plot distance, plot wetness index, soil quality) are the main key variables that were expected to influence the adoption of modern agricultural input presented in Figure 1.

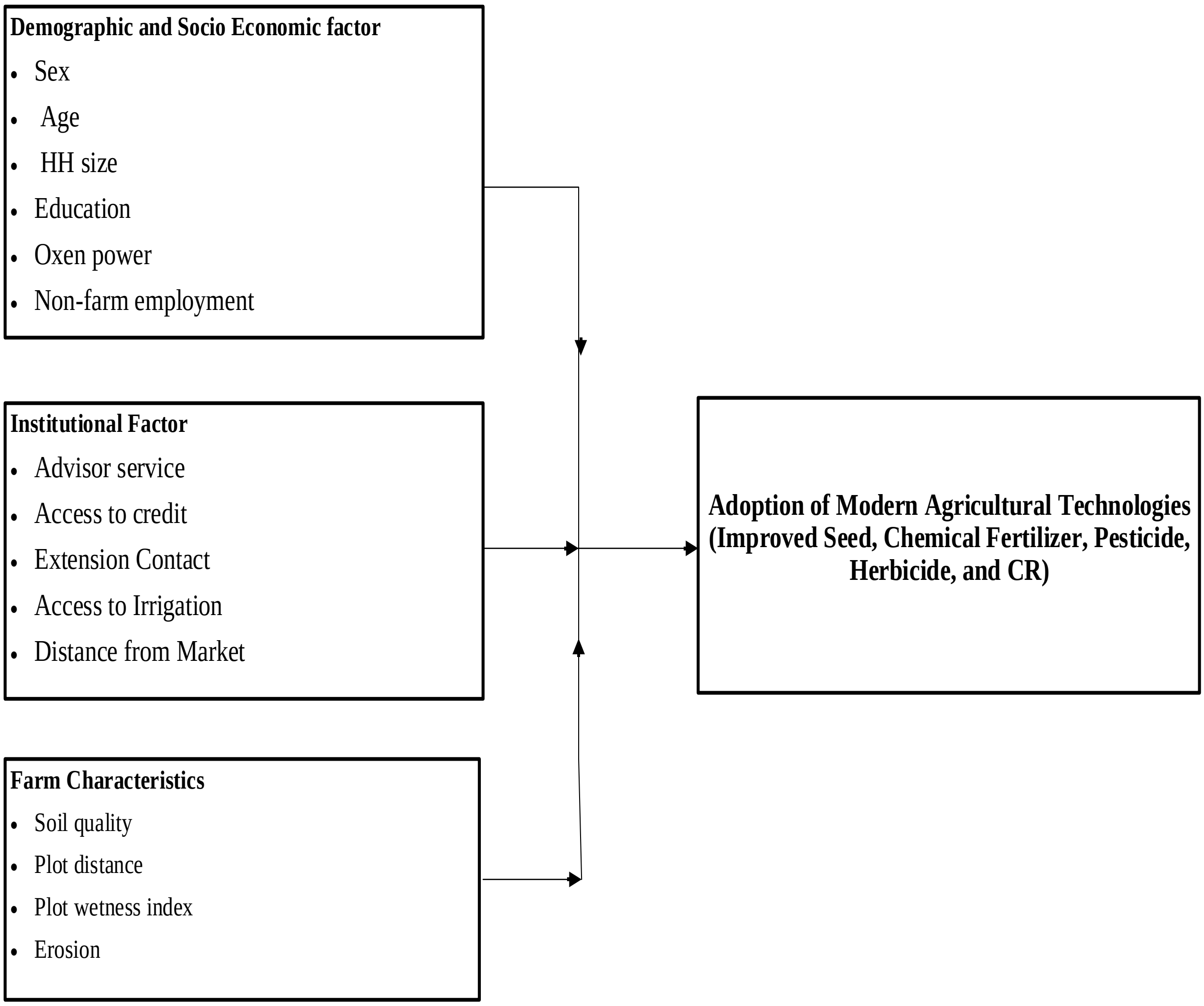

Figure 2.1: a conceptual framework of the study

Source: Source: Own conceptualization

CHAPTER THREE

3. RESEARCH METHODOLOGY

In this section, a brief description of the study area, research approach, research design, sampling methods, sources and types of data, and methods of data analysis, are presented.

3.1. Description of the Study Area

The study was conducted in Ethiopia's Amhara region. The Amhara region is located in the northwestern section of Ethiopia and has an approximate land area of 170,000 square kilometers. Amhara borders the Tigray region in the north, afar in the East-Oromiya in the south Benshangul Gumuz in the southwest, and the country of Sudan in the west. Amhara has an estimated total population of 20,136,000.88% of the population is estimated to be rural inhabitants, while 12%are urban dwellers (CSA,2007). Bahirdar is the capital city of the Amhara regional state. Amhara is divided into 11 zones and 167 woredas 3,429 kebeles. And small number of the population is engaged in the service and industry sector, nearly 84 percent of the population is in rural areas and is engaged in agriculture(United Nations Children’s Fund (UNICEF), 2016). The major economic activities of the area are mixed farming systems mainly crop production and livestock rearing.

Figure 3.1: A map showing the location of the Amhara region in Ethiopia.

Source :(Brief, R. (2022).

3.2. Data Sources, type, and Methods of Collection

The research is based on secondary data from the Ethiopian Socioeconomic Survey (ESS4), which was conducted in collaboration with the Ethiopian Central Statistics Agency (CSA) and the World Bank. It is financially supported by the Bill and Melinda Gates Foundation (BMGF) through the Living Standards Measurement Study Integrated Surveys on Agriculture (LSMS-ISA) project by extracting modern agricultural technology adopters. For the purpose of enhancing agriculture statistics and fostering better knowledge of the relationship between agriculture and other economic sectors, LSMS-ISA will gather multi-topic, household-level panel data. All nine states in the region are included in the ESS 2018/19 (ESS4) panel survey, which also includes Addis Abeba and Dire Dawa as administrative cities. So this study uses a sample representative of the Amhara region. Moreover, regular statistical reports from sources like the Ministry of Agriculture and CSA has reviewed. (ESS4 2018/2019)

3.3. Research Design

The research design of the study is a cross-sectional research design. The survey conducted by ESS4 was designed to be implemented in three visits following the AgSS field schedule. The qualitative and quantitative data conducted from sample respondents in all regions. The first visit to rural homes occurred between September and October of 2018. During the post-planting visit, livestock and agricultural surveys been distributed. A cropped cut started in the ninth and tenth of 2018. The post-harvest agricultural surveys were distributed on the second visit, this occurred between the months of the 2nd and the third of 2019. The third visit, which took place between the sixth and eighth of 2019, included the distribution of the community and home surveys. The urban household surveys were distributed in a single visit between June and August 2019. (ESS4 2018/2019)

3.4. Sampling Design

The data include information on both rural and urban areas (small, medium, and big towns); despite this, urban families have been excluded from the study since farming operations were not relevant. The CSA's 2018 pre-census mapping file of enumeration locations served as the foundation for the sample frame for the new ESS4. The ESS4 sample consists of a two-stage stratified probability sample. A stratified probability sample with two stages makes up the ESS4 sample. A portion of the AgSS EA sample consists of the rural ESS4 EAs. As a result, the subsample, which constitutes the initial stage of sampling in rural areas, is chosen using simple random sampling (SRS) from the sample of the 2018 AgSS enumeration areas (EAs).

In the second step of sampling for the ESS4, 10 agricultural households are chosen as a subsample of the households chosen for the Agss in order to be surveyed in each sampled EA using systematic random sampling from the rural EAs. ESS4 was expected to conduct interviews with 7,527 homes from 565 enumeration areas (EAs). 249 and 316 EAs, respectively, were taken from the urban and rural AgSS. 6770 households altogether, from 535 EAs, were questioned for the agriculture and home modules. Nevertheless, only the agricultural survey included 124 rural households and eight additional EAs.(ESS4 2018/2019).

Table 3.1: Surveys of EAs and HHs for ESS4 by Region and by Urban and Rural

	Urban		rural		Total	
	EAs	households	EAs	households	EAs	households
Tigray	19	283	35	398	54	681
Afar	15	225	29	321	44	546
Amhara	18	271	43	487	61	758
Oromiya	20	300	45	486	65	786
Somali	17	255	35	356	52	611
Benishangulgumuz	13	195	19	207	32	402
SNNP	18	269	40	423	58	692
Gambela	20	300	19	209	39	509
Hareri	24	360	18	191	42	551
Addis Ababa	52	778	-	-	52	778
Dire Dawa	28	419	14	161	42	580
Ethiopia	244	3655	297	3239	541	6894

From the total number of households in the Amhara region, 758 are both rural and urban households, but the study considered 487 rural farms household that are involved in farming activities.

3.5. Method of Data Analysis

After the required data was gathered the next task were data coding, data entering, data cleaning, and analysis of the prepared data. In this work, the data were analyzed using a combination of descriptive statistics and a model of econometrics.

3.5.1. Descriptive statistics

Descriptive statistics such as mean, frequencies, percentages, and standard deviation are used to a clear description of the characteristics of sample units and the extent of agricultural technologies.

3.5.2. Multivariate probit Model (MVP)

Different econometric models were applied in the literature to measure determinants of agricultural technology adoption with advantages and shortcomings. Linear probability is easiest for binary but difficult disturbance terms. Univariate model has problem to measure the potential correlation among the unobserved disturbance and relationship between different choices (Lin et al, 2005).

Multinomial logit model needs the choice variables to be mutually exclusive and assumes independence across outcomes (Cappellari & Jenkins, 2003). Multinomial probit models require multivariate normal integration to predict unknown parameters (Temesgen et al., 2009). MVP is the binary response regression model used to estimate both observed and unobserved influence on dependent variables by several independent variables simultaneously(Kariuki & Loy, 2016; Koo et al., 2014; Milioti, 2015). Multivariate probit (MVP) regression was used to estimate the factors that influenced the adoption of agricultural technologies choice. Statisticians and econometricians view the multivariate probit model used to estimate different correlated binary outcomes simultaneously (Greene, 2002). Generally, a multivariate model extends to more than two outcome variables just by adding equations. The adoption of specific technologies depends on other technological choices on a similar farm. The correlation between the various adoption choices could be the result of advancements in synergies or substitutability. When such correlation occurs, estimates of simple probit models would be inefficient and biased (P.Wainaina et al. 2016).In this study, five different agricultural technologies were identified (Improved seeds, fertilizers, pesticides, herbicides, and crop rotation).Therefore, the study has five dependent binary variables yi for farmer i .

The MVP model is typically specified as:

$$Y * im = \beta Xim + uim \qquad m = 1,2,.,.,.,5 \tag{1}$$

$$Yim = \mathbf{1}\ if\ Y * im > \mathbf{0}\ \ and\ \mathbf{0}\ is\ otherwise. \tag{2}$$

$$ui = (ui1, \; , \; , \; , \; , uiM) \sim \text{MVN}(, \text{R}) \;\; or$$

$$Y * i = (Yi1, \; , \; , \; , \; , YiM) \sim \text{MVN}(\text{xiB}, \text{R}) \qquad (3)$$

Where:

$Y * im$ This latent variable captures the degree to which a farmer views technology m as beneficial and variable describes how much a farmer thinks technologies are useful.

$X\ im$ unobserved characteristics captured by the stochastic uim.

$\beta m.$ vector of parameters to be estimated.

As a result of $y * im$ latent nature, estimation focuses on observable binary variables called yim which show whether or not a farmer utilized a certain technology in the reference year (P.Wainaina et al. 2016). A multivariate probit model was also utilized in a few earlier studies on technology adoption, such as one by Samuel and Shaibu (2019) that examined how rice farmers in Ghana adopted new agricultural technologies. The error $parameters\ uim$ $(m = 1, 2, \ldots 5)$, all having a mean of 0, are distributed in a variance-covariance matrix R with a leading diagonal of 1 and associations $Pk = Pi$ as off-diagonal elements.

$$\text{R}=\begin{Bmatrix} 1 & p12 & p13 & p14 & p15 \\ p21 & 1 & p23 & p24 & p25 \\ p31 & p32 & 1 & p34 & p35 \\ p41 & p42. & p43 & 1 & p45 \\ p51 & p52 & p53 & p54 & 1 \end{Bmatrix} \qquad (4)$$

P is the pairwise correlation coefficient of the error terms with regard to any two of the estimated adoption equations in the model. The correlation between the stochastic components of different improved technologies adopted is represented by the off-diagonal elements (e.g. $\rho ik, pki$) in the variance-covariance matrix (P.Wainaina et al.2016). The correlation is based on the principle that the adoption of a particular improved practice may depend on another (complementarity or positive correlation) or maybe influenced by an available set of substitutes (negative correlation) (Khanna, 2001).

Before running the econometric model, the data were tested against econometric problems. Accordingly, the data were checked for multi-collinearity tests for all variables done using the Variance Inflation Factor (VIF).

3.6. Definition of Variables and Hypothesis

3.6.1. Dependent variables

The dependent variables consist of dummy variables indicating the adoption of particular technologies, such as improved seeds, Fertilizers, pesticides, herbicides, and crop rotation (CR). The multivariate probit model takes binary variablesyim. which show whether or not a farmer utilized a certain technology.

Table 3.2: Dependent variables and their hypothesized

Input adoption dummies	Description and measurement
Improved seeds	Dummy = 1 if adopt improved seed, 0 otherwise
fertilizer	Dummy = 1 if farmer used fertilizers, 0 otherwise
Pesticide	Dummy = 1 if farmer adopt pesticide, 0 otherwise
Herbicide	Dummy = 1 if farmer adopt herbicide, 0 otherwise
Crop rotation (CR)	Dummy = 1 if practiced crop rotation on your land holding, 0 otherwise

3.6.2 Description of independent variables

Age of household head: One of the considerations in adoption decisions is the farmer's age. Older farmers are risk-averse and cautious about adopting new or improved technology; therefore, as their age increases, their adoption will either reduce or increase (Admassie & Ayele, 2010). Older farmers may use technology since they have more expertise and experience than younger farmers (Mohammed, 2014). Therefore, it is hypothesized that the age of the household is positive or negative influence on the adoption of modern agricultural input.

Sex of household head: The sex of the farmer has an impact on the decision to adopt; if the farmer is male-headed, there is a higher chance that the child will be adopted since they have better access to resources than female-headed farmers, such as land and labor (Hailu et al., 2014). Therefore, it is hypothesized that the sex of the household head is a positive influence on the adoption of modern agricultural input.

Household size: It describes the overall amount of farmland that a farmer owns. It is believed that a farmer will require more input the bigger his or her entire farmland holdings are. Labor (Zegeye, 2021). Therefore, it is hypothesized that family size is a positive or negative influence on the adoption of modern agricultural input.

Educational level: Higher-educated farmers can be expected to be more knowledgeable and capable of deciphering and comprehending information about developments (Belay & Mengiste, 2021). Therefore, it is hypothesized that the educational level of the household is a positive influence on the adoption of modern agricultural input.

Off-farm activity: has a negative impact on the technologies choice since they cut down on the amount of time allotted to farming (Mesele, 2019). Conversely, it could have a favorable impact on the decision to adopt since it might help farmers overcome their cash-flow problems and create money (Mulugeta & Hundie, 2012). Therefore, it is hypothesized that off-farm employment is a positive or negative influence on the adoption of modern agricultural input.

Soil quality: The quality of the crop plot's soil fertility has a positive impact on the likelihood of technologies since farmers incur costs to adopt as long as they believe doing so will increase the fertility of the soil and yield a higher return (Sebsibie et al., 2015). Therefore, it is hypothesized that soil quality positively affects the adoption of modern agricultural input.

Oxen power it is a continuous variable measured in terms of the total number of oxen. It hypothesized that the farmer who has high oxen the more likely to adopt agricultural technologies (Solomon Asfaw et al., 2011). Therefore, it is hypothesized thatoxen power positively affects the adoption of modern agricultural input.

Plot distance: The possibility of adoption is negatively impacted by the distance between the farm plot of the HH because timely plot preparation, weeding, harvesting, and input utilization are less likely (Zegeye, 2021 Therefore, it is hypothesized that plot distance negative influence.

Plot wetness index: This affects whether or not farm technology is chosen because the more humid the farm plot is (maintaining vascular plant species full), the more probable it is that alternative technologies will be implemented (soil PH, groundwater level, and soil moisture (Mesele, 2019). Therefore, it is hypothesized that the plot wetness index positive influence.

Access to credit: Farmers that have access to financing are more likely to adopt since it enables them to get past any cash flow problems they might experience when trying to purchase new agricultural packages (Belay & Mengiste, 2021). Therefore, it is hypothesized that access to credit positively affects the adoption of modern agricultural input.

Extension contact: If a farmer gets better extension service they will expect to adopt modern improved agricultural input (Abunga et al., 2012). Therefore, it is hypothesized that the extension contacts positive influence.

Advisor contact: If farmers seek guidance from both public and private groups, farm cooperatives, and agriculturalists, they are more likely to implement farming advances. This is due to the necessity of continuous and frequent access to advisory services from a variety of agents for the adoption and dissemination of farm technology (Tefera et al., 2016). Therefore, it is hypothesized that advisor service positively affects the adoption of modern agricultural input.

Distance from the market: the distance between a household and the market. Farmers will be more likely to use contemporary agricultural inputs if they are close to the market, which will have a negative impact on adoption (Mesele, 2019). Therefore, it is hypothesized that distance from the market negatively affects the adoption of modern agricultural input.

Access to irrigation: It is a dummy variable that takes the value of 1 if the household uses irrigation practices in the production season and 0 otherwise. The farmers who have used irrigation facilities allow producing high-value crops and can adopt agricultural technologies than those who solely depend on rain-fed farming (Ayalew, 2020). Therefore, access to irrigation was hypothesized to positively affect the adoption of agricultural technology.

Erosion: - Erosion is a deceptive variable a value of 1, if the field is prevented from erosion use in the production season and 0, otherwise. The farmers whose field is more prevented from soil erosion are more likely to adopt agricultural technologies. Therefore, it is hypothesized that erosion is negatively affecting was hypothesized to positively affect the adoption of agricultural technology.

Table 3.3: Independent variables and their hypothesized effects on household technology adoption

Variables	Type	Measurement of variable	Expected sign
Demographic factor			
Age of HH	Continuous	Measured in year	+/-
Sex of HH	Dummy	=1 if male ,0 otherwise	+
Household Size	Continuous	In number	+/-
Education level	Continuous	Measured in schooling year	+
Socioeconomic factor			
Off-farm activity	Dummy	=1 if they had participated ,0 otherwise	+/-
Oxen power	Continuous	In number	+
Plot factor			
Soil quality	Dummy	=1 if it is good,0 if it is poor	+
Plot distance	Continuous	In kilometre	-
Plot wetness index	Continuous	Index	+
Erosion	Dummy	1 if the field is prevented from erosion 0, otherwise	-
Institutional factor			
Access to credit	Dummy	=1 if they have access to credit,0 otherwise	+
Extension Contact	Dummy	=1 if they have an extension contact ,0 otherwise	+
Advisor contact	Dummy	=1 if advised ,0 otherwise	+
Distance from market	Continuous	In kilometre	-
Access to irrigation	Dummy	1-if accessed -0 otherwise	+

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

The chapter presents the study's overall results. Agricultural production involves the use of different package practices. These include the use of improved seed, chemical fertilizer, pesticide, herbicide, and crop rotation. Descriptive statistics were employed to describe the socio-economic, farm, demographic, and institutional characteristics of sample farmers in the rural Amhara region. Econometric analysis was also used to identify determinants of the adoption of agricultural input technology packages farming systems.

4.1. Descriptive Statistics Results

4.1.1. Current Status and Extent of Adoption

When compared to other options and suggestions, putting new technology into practice is the best way for smallholder farmers to increase production and productivity. Hence, it is vital to know how a farmer Adoption of specific technologies depends on other technological choices on a similar farm. The study identified a number of useful packages for modern agricultural input technology, and extension systems were promoting them, such as the use of improved seed, chemical fertilizer, crop rotation, pesticide, and herbicide. The extent of adoption of modern agricultural input technologies by farmers may vary depending on the socio-economic situation of the household as well as the institutional characteristics in which the household operates. The status and extent of adoption of modern agricultural technologies are discussed under the following sub-topics.

4.1.2. Adoption of agricultural technologies by farmer

Table 4.1 presents the outcomes tell that about 15.61% of the sample household practiced improved seed on farm plots. Accordingly, about 88.09% of the sample households adopt crop rotation. Only 60.99% of the farmers practiced chemicals fertilizer and 40.66% sample households adopt pesticide and also only 32.44 sample households adopt herbicide on the agricultural production. Moreover, the results of the adoption of agricultural technologies agriculture below show that the sample households adopt improved seed, chemical fertilizer, crop rotation, pesticide, herbicide with the adoption rate of 60.99%, 88.09%, respectively; the findings are shown in Table 4.1.

Table 4.1: Agricultural technologies

Technologies	Freq. (No. farmers practicing)	Percent (%)
Improved seed	487	15.61
Crop rotation	487	88.09
Chemical fertilizers	487	60.99
Pesticide	487	40.66
Herbicide	487	32.44

Source, Own Computation, 2023

4.1.3. Demographic characteristics and Socio-economic characteristics of households

The study required to find out the gender distribution among the respondents in rural Amhara region. The respondents were asked to indicate their gender, this was done to assess if gender had any influence in the adoption of agricultural input technology, and the results are shown below Table 4.2.

The result implies that number of males (362) who participated in agricultural activity was more than that of females (125). Therefore, Gender equity was not reached among the respondents that took part in this survey. This could also point out the low participation of women in agricultural activities in rural Amhara region.

Table 4.2: Sex characteristics of respondents

Sex of household head	Frequency	Percent
Female	125	25.67
Male	362	74.33
Total	487	100

Source, Own Computation, 2023

The results show in Table 4.3 indicated that the age average of farmers 47.10 years, with a minimum age of 19 and maximum age of 92 years. This indicates there is a relatively youthful age for farmers in Ethiopia. This indicated that most responders were middle-aged adults who were mature. And the mean household size is 4.22 with a standard deviation of 2.15 the minimum HH size is 1 and the maximum household size is 12.

Table 4.3: Age of sample households and house hold size

Variable	Mean	Std. dev.	Min	Max
Age of household head	47.10692	15.59422	19	92
household size	4.229645	2.152521	1	12

Source, Own Computation, 2023

The results show in table 4.4 on average, a farmer had up to 1.17 oxen in a number, with a minimum of 0 and a maximum of 6 oxen. This study suggests that a farmer had a limited number of oxen to enhance agricultural activity in the region; therefore, farmers were compelled to rent oxen as needed depending on the size of a farm.

Education can affect the adoption of agricultural technology packages. Therefore, literate farmer is estimated knowledge and use information which used to develop their adoption of agricultural technologies. Results indicates, the overall average year of formal schooling of the total sampled household heads had up to only 3 years of formal education, with a minimum of 0 level and a maximum of level-2 vocational and technical course of formal education. This indicates a low level of formal education among farmers in rural Amhara region of Ethiopia.

Off-farm income is any money derived from sources other than farming. Family members that participate in off-farm activities do so during the same calendar year as the primary farm operation. When smallholders' farm revenue is insufficient, they frequently hunt for alternative sources of money to buy food and farm inputs. Additionally, it's critical to have the extra money to pay for family members' fundamental needs. As a result, households that engaged in both on- and off-farm activities saw an increase in income and were more inclined to adopt contemporary agricultural technologies. Off-farm income can potentially make up for a cash shortage or even help pay for the buying of oxen (Million and Belay, 2004). The table presented that for the total 487 sample respondents 42 (8.62%) have engaged in off farm economics activities while the remaining 445(91.38%) sample respondents are not. The result is presented in Table 4.4

Table 4.4: Socio-economic characteristics of sample households

Summary statistics for continuous variables	Mean	Std. dev.	Min.	Max.
Oxen power	1.175481	1.062153	0	6
Education	3.222462	4.236025	0	22
Percentage distribution on categorical variable				
Non-farm activity		Freq.	Percent	
Not participated		445	91.38	
Participated		42	8.62	

Source, Own Computation, 2023

4.1.4. Technologies adoption by sex of household head

Accordingly, the results from Table indicates out of the total sample, about 15.61% of sampled households adopt improved seed and 84.39 % sampled household non adopter of improved seed during the study year, reflecting a low adoption of improved seed in agricultural production; hence 13.17% of improved seed was adopted by male's household heads.

The data revealed that 60.98% of sampled households adopt chemical fertilizer during the study year, from that 44.76% chemical fertilizer was adopted by male household heads and 16.22% adopted by the female household head, reflecting a moderate degree adoption of chemical fertilizer in rural Amhara region Ethiopia.

About, 88.09 % of sampled households practiced crop-rotation in a field during the study year from that 66.53 % practiced by the male family heads, demonstrating a high level of crop rotation practice that was once employed in Ethiopia's rural Amhara area to regulate soil fertility, prevent damage from insect pests, and control the spread of agricultural diseases, and to manage soil fertility.

The results of the study show that about 40.66% sampled households adopt pesticide in agricultural field during the study year, from that only 30.18 % adopted by male household and 10.47 female household head indicating low awareness and knowledge about the adoption of pesticide moreover, the result shows there is a low-level adoption of pesticide in rural Amhara region Ethiopia.

Accordingly, about 32.44% of sampled households adopt herbicide adopt in agricultural fields during the study year, from that only 9.65 % practiced by female household head indicating low adoption of herbicide in the female household head rather than their male counterpart, furthermore, there is low-level adoption of herbicide. Generally, the results indicated a low degree of adoption of agricultural production technologies by female household heads relative to their male counterpart, the results are showed in Table 4.5.

Table 4.5: Technologies adoption by Sex of household head

	Improved seed					**Chemical fertilizer**				
	Adopter		Non Adopter			Adopter		Non Adopter		
Sex of household head	Freq.	%	Freq.	%	Total	Freq.	%	Freq.	%	Total
Male	54	13.17	252	61.46	306	218	44.76	144	29.57	362
Female	10	2.44	94	22.93	104	79	16.22	46	9.45	125
Total	64	15.61	346	84.39	410	297	60.98	190	39.02	487
	Pesticide					**Crop rotation**				
	Adopter		Non Adopter			practiced		Not-practiced		
Sex of household head	Freq.	%	Freq.	%	Total	Freq.	%	Freq.	%	Total
Male	147	30.18	215	44.15	362	324	66.53	38	7.80	362
Female	51	10.47	74	15.20	125	105	21.56	20	4.11	125
Total	198	40.66	289	59.34	487	429	88.09	58	11.91	487
					Herbicide					
	Adopter				Non- adopter					

Sex of household head	Freq.	%	Freq.	%	Total
Male	111	22.79	251	16.02	362
Female	47	9.65	78	51.54	125
Total	158	32.44	329	67.59	487

Source, Own Computation, 2023

4.1.5. Farm characteristics of household

Farm characteristics soil quality, erosion, plot distance, plot wetness index are other factors that affect the adoption decision. The mean Plot distance is 6.16 kilometer with standard deviation 12.23 and the minimum 1 and max 59 kilometers. And the mean plot wetness index 11.98 index with standard deviation 2.53. About 80.08% of sampled household farm are prevented from erosion and 19.92 % sampled household farm are not prevented from erosion during the study year, and about 47.02 soils are fertile (good) and 52.98 soils are poor**.** The farm characteristics of sample households presented in Table 4.6.

Table 4.6: farm characteristics of sample households

Percentage distribution on categorical variable	Prevented from Erosion		Not Prevented from Erosion	
	Freq.	Percent	Freq.	percent
Erosion	390	80.08	97	19.92
soil quality	Good soil		Poor soil	
	229	47.02	258	52.98
Summary statistics for continuous variables	Mean	Std. dev.	Min	Max
plot distance	6.162584	12.23442	1	59
plot wetness index	11.98441	2.530568	0	36

4.1.6. Institutional characteristics

Institutional characteristics such as extension service, advisory service, credit access, and access to irrigation are other factors that affect the adoption decision. The first two is related with farmers' access to information on different packages and its profitability while access to credit indicates farmers' ability to finance their purchase of modern technology under cash constraints (Kassie et al. (2010).

Table 4.7: Institutional characteristics of sample household

Percentage distribution on categorical variable	Adopter		Non adopter	
	Freq.	Percent	Freq.	Percent
Credit service	141	28.95	346	71.05
Advisory service	381	78.23	106	21.77
Extension program,	259	53.18	228	46.82
Access to irrigation	102	20.94	385	79.06
Summary statistics for continuous variables	Mean	Std. dev.	Min	Max
Distance from market	61.7691	34.50446	1.1	117.6

Source, Own Computation, 2023

4.1.6.1. Access to Credit

The availability of credit was found to be a significant economic factor, especially for farmers who lack the necessary funds to buy agricultural inputs. Farmers who lack the necessary funds to buy it are the ones who are most likely to adopt new technology. As a result, farmers were greatly aided in their adoption of new technologies by the availability of credit. 28.95% of respondents had access to credit to purchase agricultural inputs, while 71.05 percent did not.

4.1.6.2. Contact with extension agent and advisory service

As showed in Table 4.7 from the total sample household 53.18 percent had contact with an extension agent and 46.82 percent had no contact with an extension agent and 78.23 percent of sample respondents got advisory service and 21.77 percent of sample households did not access advisory service about the adoption of modern agricultural technologies.

4.1.6.3. Distance from Market

Distance is another significant situational or institutional factor that affects the decision to adopt new technology. Households located close to the market center can travel more frequently than those located farther away. These encouraged farmers to employ more advanced agricultural technology. As depicted in the table 4.7 from the total sample household the maximum km farmers travel 117.6 Km and the minimum 1.1 Km.

4.2. Determinants of adoption of agricultural input technologies packages

Results of the multivariate probit model were presented and discussed. Many factors are expected to affect the adoption of modern agricultural technologies based on theoretical models and empirical evidence.so before running the model, the explanatory variable fitted to the MVP model were tested for the existence of outliers and collinearities. The existence of outliers was checked for basic explanatory variables. There is the absence of multi-collinearity between explanatory variables with $VIF = 4.16$.

MVP model is significant, because the null hypothesis that the probabilities of adoption of the five agricultural technologies packages are independent were rejected at the 1 % significance level .the model results revealed that the Wald test (Wald chi2 (80) = 182.68; Prob > chi2 = 0.000) is significant at the 1% significance level ,which indicate that the subset of coefficients of the model is jointly significant and that the explanatory power of the factors included in the model is satisfactory. Furthermore, the results of correlation coefficients of the error terms also indicate interdependence among the decisions to use technology options by farmers. The results support the assumption of interdependence between the different technology options. The maximum likelihood methods of estimation result suggested a positive and significant interdependence between household decisions to adopt improved seed, chemical fertilizer, pesticide, herbicide, crop rotation. The results revealed that several hypothesized demographic, socio economic, farm and institutional variables have a significant effect on decision to use agricultural input technologies.

Age of household head: Age was positively related to the adoption of pesticide a 10 % level of significance; the findings are shown in Table 4.8. This implies that older farmers are more likely to adopt pesticide than younger farmers. Older farmers might have resources and experience that would provide them with greater opportunities to experiment with new technologies. Contradicting the finding of (zegeye 2021) the result indicates young farmers are more likely to adopt farm technology due to better education, willingness, and adaptability.

Sex of household head: As the results indicate the sex of the household head had a positive and significant influence on the adoption of improved seed and crop rotation at a 10%, 5% level of significance respectively the findings are shown in Table 4.8. This implies that the positive sign of the coefficient indicates that male-headed households were more likely to adopt improved seed and crop rotation technologies than female-headed household heads.

Those male headed households who have more access to information to use innovation than female headed households, and also Male headed household has better access to participate in training, workshop and has better exposure to information which helps to adopt agricultural technologies more easily than female headed household because of female headed household have a capacity to influence by the cultural norms and traditions. This is consistent with (Regassa etal. 2003; Almaz and Begashaw, 2019) indicates that sex of household positive and significant in adoption of agricultural technologies which means male farmers have more access to information, extension and credit services than their female headed households.

Education: Education was found to have a positive and significant relationship with the adoption improved seed at 10% level of significance. The findings are shown in Table 4.8. This implies that higher educational status increases the awareness of farmer about the benefits of applying improved seed. Better-educated farmers have more profitable income sources and fewer capital constraints. While education had a positive and significant. This is consistent with (Massresha et al., 2021). Due to more educated farmers in the study area are more likely to adopt because they are better able to gather, analyze, and assess knowledge on contemporary technology, market opportunities, and its implication benefits.

Soil quality: - The result revealed that soil quality was positive and significantly related to the adoption pesticide at 5% level of significance to adopt of pesticide; the findings are shown in Table 4.8. This implies that the farmers whose farmland was fertile more likely to adopt pesticide than those have infertile soil. Soil fertility is the ability of soil to sustain plant growth and optimize crop yield by using pesticide for soil invertebrates provide essential ecosystem benefit like cycling nutrients that for life to exist and for plant growth, dead plants and animals should decompose, controlling pests and disease. This is consistent with (De Ridder and Van Keulen, 1990) indicates the application of improved seed, chemical fertilizer increases the supply of nutrients to the crop and increases the organic matter content of the soil.

Extension Contact: - household extension contact was significant and positively allied to the decision to adopt, chemical fertilizer and herbicide at 1%, 10% level of significance respectively, the findings are shown in Table 4.8. This implies the access to extension service creates a chance to the farmers encouraging choosing leading-edge agricultural methods. Therefore, we can deduce that the higher the number of extensions visits to farmers, the higher the likelihood of preference to adopt modern agricultural technology. The local government's extension agency aids in raising farmers' awareness of the nature and characteristics of technology, as well as its use and effects. this is in line with (Massresha et al., 2021; 2016; Belay & Mengiste, 2021) indicates Farmers can learn about new technologies from extension contact.

Credit access: - The result reveled that, it had a positive and significant influence on the adoption of chemical fertilizer at a 5% significance level, the results are shown in Table 4.8. This implies that those households who have access to credit are more likely to adopt agricultural technologies than those who have no access to formal credit. Hence, the accessibility of credit from appropriate sources helps farmers to purchase chemical fertilizers. Inputs for agriculture can be purchased on credit by smallholder farmers, helping them to unwind while inputs are being distributed. This is consistent with (Zegeye, 2021) this is because of credit access solves income problems that household could face while they want to purchase agricultural technologies; and hence paves the way for timely application of modern farm inputs.

Advisory service: - As the multivariate probit model result indicates, it had a positive and significant influence on the adoption of improved seed and crop rotation at a 5%, and 10 % significance level respectively, and also negatively and significantly related to the adoption of chemical fertilizer at 10% significant level, this implies that having access to regular and frequent advisory services by development agents, farm cooperatives and meetings plays a fundamental role in the dissemination and adoption of improved seed and crop rotation. Result is in line with (Tefera et al., 2016; Sebsibie et al., 2015). Advisory services show that regular and frequent advising services provided by development agents, farm cooperatives, and meetings are essential for the spread and uptake of agricultural technology. And farmers not having access to information about the use of chemical fertilizers this finding did not meet the a priori expectation since the agricultural advisory service is meant to influence technology uptake by farmers. This is consistent with (Samuel et al. 2019) posit that the household advisory service does not promote cross-learning and experience sharing among farmers from different homes and backgrounds since it is carried out only within the household of the person transmitting the information.

Non-farm activity: - as the multivariate probit model result indicates, it had a negative and significant influence on the adoption of pesticides at a 10% significance level shown in Table 4.8. This implies that application of pesticide is labour intensive and if farmers are engaged in off /non-farm activities they will not have labour for this activity. This finding contradicts the work of (Ayenew et al., 2020) this indicates that Farm households who participate in off-farm activity are also more likely to adopt technologies packages.

Oxen power: - As the multivariate probit model result indicates, it had a positive and significant influence on the adoption of chemical fertilizer, herbicide, and crop rotation at a 1%, 5%, and 1% significance level, respectively, the results are shown in Table 4.8. this implies that increase number of oxen increase adoption of technologies packages, because oxen provides a draught power, manure fertilizer and a source of income to purchase technologies. This result is consistent with (Endrias Geta et al. 2010).

Irrigation: - As the multivariate probit model result indicates, it had a positive and significant influence on the adoption of herbicide at a 10% significance level, the results are shown in Table 4.8. this implies access of irrigation create a chance to adopt herbicide and irrigation greatly increase herbicide performance in dry soil and water moves the herbicide from the soil surface and in to the soil and contribute the amount of herbicide available for absorption by weeds .so irrigation is essential for the observation of nutrient element by the crop plants from the soil .because herbicide help the crops grow by destroying the weed that is robbing the crop of water, nutrient and sunlight .and irrigation improve the efficiency of herbicide application. This in consistent with (Ayalew, 2020). Indicates that the farmers who have used irrigation facilities allow producing high-value crops and can adopt agricultural technologies than those who solely depend on rain-fed farming.

Erosion: - As the multivariate probit model result indicates, it had a positive and significant influence on the adoption of pesticide and crop rotation at a 10%, and 5% significance level, and the results are shown in Table 4.8.this implies that the farmers whose field is more prevented from soil erosion are more likely to adopt pesticide and crop rotation the farm prevent from erosion is used to easily applicable the pesticide in farm .Crop rotation can improve soil structure and fertility by alternating deep-rooted and shallow rooted plants. in turn this can reduce erosion and increase infiltration capacity, thereby reducing downstream flood risk .it gives various benefit to the soil.

Distance from market: - As the multivariate probit model result indicates, it had a positive and significant influence on the adoption of chemical fertilizer at a 1% significance level the results are shown in Table 4.8, this implies that Farmers living near to the market can easily purchase chemical fertilizer, Better access to markets enables farmers to obtain market information and other important inputs they may need. This finding contradicts the work of (Dawit and Abduselam, 2018). A plausible explanation for this contradicting result would be when farmers are far from the market, the transaction cost for acquiring inputs will be high and this will, in turn, reduce the relative advantage of adopting new technologies.

Table 4.8: Result of multivariate probit model

VARIABLES	(1) Improved seed Coef.(S.E)	(2) Chemical fertilizers Coef.(S.E)	(3) Pesticide Coef(S.E)	(4) Herbicide Coef(S.E)	(5) Crop rotation Coef(S.E)
Age of HH	-0.000	0.007	0.009*	0.007	-0.000
	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
Sex of HH	0.445*	0.216	0.128	-0.327	0.490**
	(0.252)	(0.198)	(0.201)	(0.208)	(0.236)
Household Size	0.000	-0.002	-0.000	0.052	0.055
	(0.047)	(0.040)	(0.041)	(0.041)	(0.051)
Education	0.032*	-0.022	0.018	-0.010	0.023
	(0.019)	(0.018)	(0.017)	(0.019)	(0.025)
Oxen power	-0.058	0.287***	0.076	0.194**	0.466***
	(0.092)	(0.081)	(0.076)	(0.084)	(0.117)
Non-farm activity	-0.283	-0.233	-0.971*	-0.098	0.660
	(0.424)	(0.363)	(0.539)	(0.492)	(0.644)
Soil quality	0.121	-0.141	0.218**	0.147	0.106
	(0.125)	(0.109)	(0.107)	(0.117)	(0.139)
Erosion	-0.308	-0.148	0.344*	0.010	0.511**
	(0.203)	(0.198)	(0.191)	(0.198)	(0.217)
Plot wetness index	0.001	0.051	-0.042	-0.046	-0.042
	(0.039)	(0.033)	(0.036)	(0.035)	(0.045)
Plot Distance	-0.013	-0.004	-0.003	0.002	0.006
	(0.009)	(0.006)	(0.006)	(0.006)	(0.010)
Irrigation	-0.364	-0.215	0.098	0.365*	-0.066
	(0.288)	(0.209)	(0.203)	(0.212)	(0.272)
Extension program	-0.050	0.971***	-0.157	0.314*	0.314
	(0.183)	(0.159)	(0.156)	(0.173)	(0.208)
Advisory service	0.630**	-0.372*	-0.124	-0.320	0.432*
	(0.277)	(0.198)	(0.200)	(0.210)	(0.227)
Credit services	0.174	0.587**	-0.333	-0.407	0.432
	(0.245)	(0.235)	(0.227)	(0.254)	(0.334)
Distance market	0.000	0.008***	-0.001	0.001	-0.001
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Constant	-1.646**	-1.433**	-0.967	-1.053*	-0.502
	(0.677)	(0.595)	(0.613)	(0.636)	(0.758)
Observations	487	487	487	487	487

Note obs =487 Log likelihood = -722.21097 Wald chi2 (80) = 182.68 Prob > chi2 = 0.000

And *** p<0.01, ** p<0.05, * p<0.1 level of significance respectively

Source: Own Computation, 2023

The results show in table 4.9 after running the MVP regression, the correlation matrix of the technologies from the MVP model model also showed that farmers have adopted number of agricultural technologies packages simultaneously. this finding was tested using pair-wise correlation coefficients across the residuals of the multivariate probit model. The coefficients measure the correlation between the adoptions decisions of the agricultural technologies considered, after the influence of the observed factors has been accounted for. The result support the hypothesis that the error term of multiple agricultural technologies package was influenced by different sets of factors and at different level of significance by the same factor. A non-zero correlation coefficient implies that there are unobservable factors influencing the choice of technologies and the decision to adopt them. The results of the correlation coefficients of the error terms from the MVP are significant for any pair of equations (p= 0.000), and they are statistically different from zero in five of the six cases (Table 4.9), confirming the appropriateness of the MVP specification. It shows that the joint probability of using all technologies was 11.8 percent, and the joint probability of failure to adopt all technologies was 3.2 percent. The results of the correlation coefficients of the error terms indicate that there is a positive (complementarity). the result showed a significant positive association (showing complementary and synergies) between pesticide and improved seed at 5% significant level, herbicide and chemical fertilizers at 5 % significant level, crop rotation and chemical fertilizers at 5% significant level, herbicide and pesticide t 1% significant level, crop rotation and pesticide at 10% significant level ,crop rotation and herbicide at 10% significant level ,suggesting that the adoption of one technology would enhance the chance of adopting another. And the highest correlation was between the adoption of herbicide and pesticide (76.58%).

Table 4.9: Correlation matrix of the technologies from the multivariate probit model

	Improved seed	Chemical fertilizer	Pesticide	Herbicide	Crop rotation
Improved seed	1.0000				
Chemical fertilizer	0.0737	1.0000			
Pesticide	0.1557**	0.0579	1.0000		
Herbicide	0.1684	0.0417**	0.7658***	1.0000	
Crop rotation	0.0226	0.1738**	0.0720*	0.0788*	1.0000

*** p<0.01, ** p<0.05, * p<0.1 indicates level of significance.

Source: Own Computation, 2023.

CHAPTER FIVE

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATION

5.1. Summary

Agriculture is the backbone of Ethiopia's economy. Since reducing extreme poverty is the primary issue, increasing agricultural production a crucial solution is considered to be increased productivity and output via the integration of improved agricultural technologies. This study aimed at analyzing the determinants of agricultural input technologies adoption by smallholder farmers in rural Amhara regional state, Ethiopia, the major goals of this study were to identify the variables influencing smallholders' adoption choices and assess the extent to which farmers adopted in a research area. The study takes data from the ESS4 data collected in 2018/2019. 487 farm household head were taken as samples for this study. Data analysis was carried out using descriptive statistics and econometric techniques. Multivarite probit model was employed. The purpose of conducting those tests is to get sound results from the estimation of the MVP model. For instance, multicollinearity, hetrosckedasticity test, and model fitness tests were conducted. Results of descriptive analysis showed that out of the total interviewed farmers 362 (74.33%) were male and the remaining 125 (25.67%) were female household head. The average age of the sample household head was 47.10 years. Moreover, the results of the adoption of agricultural technologies reveal that 88.09 %, 60.99%, 40.66%, 32.44%, and 15.61% of the respondents adopt crop rotation, chemical fertilizer, pesticide, herbicide, and improved seed respectively. Moreover, higher proportions of adopters (88.09 %) practiced crop rotation; while lower proportions of farmers (15.61%) adopted improved seeds. The result of the study revealed that farm households' decision to adopt improved seeds significantly influenced by sex, education, and advisory service. Whereas, the adoption of chemical fertilizer is influenced by extension contact, access to credit, advisory service, oxen power, and distance from the market. And also the adoption of pesticides significantly influences by age, soil quality, and erosion. Furthermore, the farmer's decision to adopt herbicide is significantly influenced by extension contact, oxen power, access to credit, and irrigation. And farm household's decision to adopt Crop rotation significantly influenced by sex, advisory service, oxen power, and erosion.

5.2. Conclusions

Adoption of modern agricultural technologies is influenced by many factors. These factors differ with different farmers living in different geographical environments and different socio-cultural point of view and in different economic environments with different farming investment capitals. The choice of farm households in the study area to embrace recent or enhanced farm technologies is primarily impacted by a variety of demographic, institutional, socioeconomic, and farm variables. To achieve the objectives of the study, descriptive statistics and a multivariate probit model were used. A multivariate probit model result has suggested that the age of the household head was positively and significantly related to pesticides. The sex of the household head was positive and significantly related to improved seed, and crop rotation. Being a male household head had a higher probability to adopt new agricultural technologies and the use of improved seeds was discovered to be positively and significantly correlated with education. Oxen power was positively and significant relationship with the adoption of chemical fertilizers, crop rotation, and herbicides. Non-farm activity was negatively and significant relationship with the adoption of pesticides. Soil quality was positively and significant relationship with pesticides. And erosion was positively and significant relationship with pesticide and crop rotation. Access to irrigation was positively and significant relationship with herbicides. Extension contact was positively and significant relationship with chemical fertilizer and herbicides. Advisory service was positively and significant relationship with crop rotation and improved seed and negatively and significant relationship with chemical fertilizer. Credit service and distance from the market was positively and significant relationship with chemical fertilizer. The relationships among all agricultural technologies were positive. There are complementarities among modern agricultural technologies.

5.3. Recommendations

When creating diverse strategies and initiatives to put into place for the nation's overall development of the agricultural sector, and the study area in particular, the government should take into consideration the aforementioned significant variables, especially concerning in accordance with the aforementioned findings, a couple of suggestions are made in the examined area:

- The participation of women in agricultural activities in general and in adoption of modern agricultural technologies is low in the study area. so by considering a widespread and comprehensive development of the country the involvement of female empowerment is crucial to the overall growth of the country ,Given the proportion of women in the society and their role in agriculture they should be encouraged to participate in agricultural extension. Hence, the government should adopt a policy that empowers female-headed households to participate in diverse institutions and be agents of change.

- The government should work target on older household heads; they are more likely to adopt modern agricultural technologies. Hence, introducing new agricultural technology in the areas may be effective if it emphasizes more on older farmers because older farmers might have resources and experience that would provide them with greater opportunities to experiment with new technologies.
- Government should support adequate and effective basic educational opportunities for the rural farmers in Amhara are more crucial.
- Government should adopt a policy for strengthening access to information about farm technologies by increasing the availability and quality of extension services, encouraging the participation of farmers in training centers, and providing advisory services to increase the adoption by farm households. The detrimental impact of a lack of years of formal education on the decision to adopt farm technologies can be offset by the influence of extension services, training, and advisory services. Thus, policies for strengthening the extension service and advisory service delivery capabilities through technical support and short and long-term training programs are important in adoption decisions.
- The likelihood of adopting alternative farm technology packages is significantly influenced by access to credit. This may indicate the necessity for and growth of microfinance institutions in Ethiopian and local government rural areas where farmers' access to capital poses a significant barrier to embracing technology. This could indicate that adopting farm technologies requires a lot of money; hence loans should be available to the rural poor.
- A path to increasing agricultural productivity is provided by irrigation development and intensification, which also enhance crop growth and quality. The government needs to support irrigation because it increases food security by enabling farmers to cultivate crops regularly and also Government should give more attention in prevented soil from erosion.

- Farmers who are small-scale and Govt. ought to collaborate together to build well-constructed and easily accessible roads to easily deliver their product to the market that means improving the existing market center in the study area through construction of whether roads and providing good transport facilities for farmers need to be given more attention.
- Currently, The Amhara region's farm households recognize the importance of agricultural technologies, but their adoption is limited by issues related to household characteristics, socioeconomic conditions, institutional structures, and farm features. To promote the agrarian poor's use of agrarian technology and better comprehend farmer's needs and adoption capacities to develop technology that will work for them, to enhance the use of technology, policymakers ought to offer more precise targeting of implementation and suitable facilities for rural farmers.

- **Area for further research**

The study set suggestions for future research; it has several shortcomings because it only looks at the long-term impact of implementing agricultural innovations in the research region and because the study only used data from cross-sectional surveys. Applying data from panels (as well as an extended dimension) to identify the innate and long-lasting variables that impact adoption options, more investigation into the factors influencing the adoption of technological advances in agriculture is advised. This research only addresses difficulties on the client's side. This research is also recommended for examining the factors that influence supply-side concerns in the implementation of agricultural technologies.

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7. APPENDICES

Appendix Table 1: Results of multivariate probit regression for improved seed

improved seed	Coefficient	Std. err.	Z	P>z	[95% conf. interval]	
Age of HH	-.0001824	.005592	-0.03	0.974	-.0111426	.0107778
Sex of HH	.4451189	.2523517	1.76	0.078	-.0494813	.9397191
Household Size	.0004912	.0468023	0.01	0.992	-.0912396	.0922221
education	.0320703	.0189038	1.70	0.090	-.0049805	.0691211
oxen power	-.058121	.0923932	-0.63	0.529	-.2392085	.1229664
Non-farm activity	-.2828665	.4241801	-0.67	0.505	-1.114244	.5485112
Soil quality	.1214476	.1253286	0.97	0.333	-.1241919	.3670871
Erosion	-.3083827	.2031765	-1.52	0.129	-.7066013	.0898359
Plot wetness index	.0008632	.0386815	0.02	0.982	-.0749511	.0766775
Plot Distance	-.0132017	.008904	-1.48	0.138	-.0306532	.0042499
irrigation	-.3641121	.2879539	-1.26	0.206	-.9284914	.2002672
extension program	-.0497832	.1830348	-0.27	0.786	-.4085248	.3089584
Advisory service	.6302919	.2773891	2.27	0.023	.0866192	1.173965
credit services	.1739467	.2454787	0.71	0.479	-.3071827	.655076
Distance market	.0001858	.0027912	0.07	0.947	-.0052847	.0056564
_cons	-1.646205	.6772157	-2.43	0.015	-2.973523	-.3188861

Appendix Table 2: Results of multivariate probit regression for chemical fertilizer

chemical fertilizers						
Age of HH	.0065206	.004991	1.31	0.191	-.0032616	.0163028
Sex of HH	.2159607	.1984902	1.09	0.277	-.173073	.6049943
Household Size	-.0021864	.0398131	-0.05	0.956	-.0802186	.0758459

Education	-.0217276	.0175539	-1.24	0.216	-.0561326	.0126773
Oxen power	.2874727	.0810763	3.55	0.000	.1285662	.4463793
Non-farm activity	-.2330402	.3630994	-0.64	0.521	-.9447019	.4786215
Soil quality	-.1412128	.1088414	-1.30	0.194	-.3545379	.0721124
Erosion	-.1475912	.1979689	-0.75	0.456	-.5356032	.2404208
Plot wetness index	.0511721	.0329772	1.55	0.121	-.0134619	.1158062
Plot Distance	-.0041354	.0060677	-0.68	0.496	-.0160279	.0077571
Irrigation	-.2147924	.208787	-1.03	0.304	-.6240073	.1944226
Extension program	.9714958	.1589492	6.11	0.000	.6599611	1.283031
Advisory service	-.3721693	.1984197	-1.88	0.061	-.7610648	.0167261
Credit services	.5872956	.234752	2.50	0.012	.1271901	1.047401
Distance market	.0078703	.0023712	3.32	0.001	.0032229	.0125177
_cons	-1.432757	.59462	-2.41	0.016	-2.598191	-.2673234

Appendix Table 3: Results of multivariate probit regression for pesticide

pesticide						
Age of HH	.0092926	.0048718	1.91	0.056	-.000256	.0188411
Sex of HH	.1283213	.2013923	0.64	0.524	-.2664004	.523043
Household Size	-.0002702	.040562	-0.01	0.995	-.0797703	.0792299
Education	.0179441	.0165453	1.08	0.278	-.0144842	.0503724
Oxen power	.076003	.0760381	1.00	0.318	-.073029	.225035
Non-farm activity	-.9711031	.5385248	-1.80	0.071	-2.026592	.0843862
Soil quality	.2175741	.1071565	2.03	0.042	.0075512	.4275971
Erosion	.3441883	.1908595	1.80	0.071	-.0298896	.7182661
Plot wetness index	-.0416539	.03583	-1.16	0.245	-.1118795	.0285717
Plot Distance	-.0026153	.0062001	-0.42	0.673	-.0147672	.0095367
Irrigation	.0984905	.202517	0.49	0.627	-.2984356	.4954166
Extension program	-.1570796	.1564802	-1.00	0.315	-.4637751	.1496159
Advisory service	-.1241191	.199604	-0.62	0.534	-.5153357	.2670975

credit services	-.3327702	.2271947	-1.46	0.143	-.7780637	.1125232
Distance market	-.0007773	.0023234	-0.33	0.738	-.0053311	.0037766
_cons	-.9667025	.6133787	-1.58	0.115	-2.168903	.2354976

Appendix Tables 4: Results of multivariate probit regression for herbicide

herbicide						
Age of HH	.0071861	.0052776	1.36	0.173	-.0031578	.01753
Sex of HH	-.3274817	.2076334	-1.58	0.115	-.7344356	.0794723
Household Size	.0520461	.0413283	1.26	0.208	-.0289559	.133048
Education	-.0099997	.0185635	-0.54	0.590	-.0463836	.0263841
Oxen power	.1938948	.0844676	2.30	0.022	.0283413	.3594482
Non-farm activity	-.0975935	.491816	-0.20	0.843	-1.061535	.8663482
Soil quality	.1468112	.1170213	1.25	0.210	-.0825462	.3761687
Erosion	.0102617	.1977149	0.05	0.959	-.3772523	.3977758
Plot wetness index	-.0462463	.0354531	-1.30	0.192	-.1157331	.0232406
Plot Distance	.0020311	.0063726	0.32	0.750	-.0104591	.0145212
Irrigation	.3648732	.211723	1.72	0.085	-.0500963	.7798427
Extension program	.3139715	.1728454	1.82	0.069	-.0247992	.6527422
Advisory service	-.3203559	.2103678	-1.52	0.128	-.7326692	.0919574
Credit services	-.4068752	.2539828	-1.60	0.109	-.9046724	.090922
Distance market	.000801	.0024575	0.33	0.744	-.0040157	.0056177
_cons	-1.053071	.6356226	-1.66	0.098	-2.298868	.1927268

Appendix Tables 5: Results of multivariate probit regression for crop rotation

Crop Rotation						
Age of HH	-.0001679	.0060859	-0.03	0.978	-.0120961	.0117603
Sex of HH	.4897841	.2356607	2.08	0.038	.0278975	.9516706
Household Size	.0549075	.0505031	1.09	0.277	-.0440766	.1538917
Education	.0226754	.0245475	0.92	0.356	-.0254367	.0707876
Oxen power	.4662253	.1169352	3.99	0.000	.2370365	.6954141
Non-farm activity	.6604628	.6443955	1.02	0.305	-.6025291	1.923455
Soil quality	.1060875	.1387015	0.76	0.444	-.1657625	.3779374
Erosion	.5106684	.2170972	2.35	0.019	.0851657	.9361711
Plot wetness index	-.0420116	.0451376	-0.93	0.352	-.1304796	.0464564
Plot Distance	.0055614	.0095465	0.58	0.560	-.0131494	.0242721

Irrigation	-.0664315	.2718228	-0.24	0.807	-.5991944	.4663314
Extension program	.3139158	.2081235	1.51	0.131	-.0939988	.7218303
Advisory service	.4317154	.2273803	1.90	0.058	-.0139418	.8773726
Credit services	.4322387	.3336584	1.30	0.195	-.2217197	1.086197
Distance market	-.0013538	.0031593	-0.43	0.668	-.0075459	.0048382
_cons	-.5023728	.75838	-0.66	0.508	-1.98877	.9840247

Appendix Table 6: Estimate Correlation coefficient for the error term from the MVP regression

/atrho21	-.1582574	.1094341	-1.45	0.148	-.3727443	.0562295
/atrho31	.2225969	.097332	2.29	0.022	.0318297	.413364
/atrho41	-.0959645	.108506	-0.88	0.376	-.3086323	.1167032
/atrho51	-.1485368	.1261039	-1.18	0.239	-.395696	.0986223
/atrho32	-.0475946	.0941318	-0.51	0.613	-.2320896	.1369003
/atrho42	.1963073	.0960549	2.04	0.041	.0080432	.3845713
/atrho52	.2861682	.1216225	2.35	0.019	.0477924	.524544
/atrho43	1.265867	.1454327	8.70	0.000	.9808242	1.55091
/atrho53	.2006184	.1157989	1.73	0.083	-.0263432	.42758
/atrho54	.2214209	.1258769	1.76	0.079	-.0252933	.4681351
rho21	-.1569493	.1067384	-1.47	0.141	-.3563898	.0561703
rho31	.2189918	.0926642	2.36	0.018	.031819	.3913253
rho41	-.095671	.1075128	-0.89	0.374	-.2991923	.1161763
rho51	-.147454	.1233621	-1.20	0.232	-.3762603	.0983038
rho32	-.0475587	.0939189	-0.51	0.613	-.2280102	.1360514
rho42	.1938239	.0924463	2.10	0.036	.008043	.3666708
rho52	.2786042	.1121822	2.48	0.013	.047756	.4811994
rho43	.8526735	.0396955	21.48	0.000	.7534225	.9139355
rho53	.1979696	.1112605	1.78	0.075	-.0263371	.4032969
rho54	.2178719	.1199018	1.82	0.069	-.0252879	.4366913

Appendix Table 7: Joint probability test from MVP model

Variable	Mean Std. dev.	Min	Max
xb1	-1.100576 .4562975	-2.74518	.140617
xb2	.2576196 .703199	-1.599955	2.076266
xb3	-.6092352 .4016815	-2.179508	.2945634
xb4	-.9429629 .4246616	-2.097477	.2778109
xb5	1.315112 .7978724	-1.040307	4.324487
pmard1	.1578821 .0936906	.0030239	.5559137
pmard2	.5819247 .2305554	.0548043	.9810653
pmard3	.2867016 .1207798	.014647	.6158363
pmard4	.1926816 .1124658	.0179757	.6094213
pmard5	.8483929 .1646811	.1490988	.9999924
stdp1	.3596144 .0998393	.1891449	1.039707
stdp2	.3017756 .0765645	.164451	.884583
stdp3	.305816 .0963328	.1641371	.9572641
stdp4	.3224504 .0897016	.1758476	.9652004
stdp5	.4066198 .1291578	.2143231	1.159006
pall1s	.118578 .0127052	.0001121	.3746879
pall0s	.03219604 .0727936	0.000011	.1139358

Note:

- **xb** is calculate the liner prediction for each equation
- **Stdp** is calculate the standard error of the linear prediction(xb)
- **Pmarg** is calculate marginal probit predicted probability of success for outcome
- **Pall** is calculate the probit predicted - joint probability of success in every outcome pr(depvar i)=1

Joint probability of failure in every outcome pr(depvari)=0

Appendix Table 8: Result from Variance Inflation Factor (VIF)

VIF		
Variable	VIF	1/VIF
Plot wetne~x	14.86	0.067306
Age_of_HH	8.98	0.111298
Householder	6.59	0.151657
Advisory se~e	5.82	0.171836
Sex of HH	5.30	0.188780
Erosion	4.90	0.204256
Distance market	4.22	0.237019
Oxen power	2.44	0.410528
Extension ~m	2.29	0.437390
Soil quality	1.73	0.576420
Education	1.61	0.621775
Plot Dista~e	1.35	0.743379
Irrigation	1.27	0.784532
Credit ser~s	1.25	0.798575
non_farm_a~1	1.10	0.908039
Mean VIF	4.16	

Appendix Table 9: Table Result from model test

Number of observation	487
Wald chi2 (80)	182.68
Log likelihood	-722.21
Prob > chi2	0.0000*
Joint probability(success)	0.118
Joint probability(failure)	0.032