2024-07

Lime Technology Adoption and its Determinants: the Case of Debre Elias District, East Gojjam, Amhara, Ethiopia

Tirngo Solomon Adamu

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIROMENTAL SCINCES

GRADUATE PROGRAM IN AGRICULTURAL ECONOMICS DEPARTMENT

LIME TECHNOLOGY ADOPTION AND ITS DETERMINANTS: THE CASE OF DEBRE ELIAS DISTRICT, EAST GOJJAM, AMHARA, ETHIOPIA

M.Sc. Thesis

By

Tirngo Solomon Adamu

July, 2024

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIROMENTAL SCINCES

GRADUATE PROGRAM IN AGRICULTURAL ECONOMICS DEPARTMENT

Lime Technology Adoption and Its Determinants: The Case of Debre Elias District, East Gojjam, Amhara, Ethiopia

M.Sc. Thesis

By

Tirngo Solomon Adamu

Submitted in Partial Fulfillment of the Requirements for The Degree of Master of Science (M.Sc.) In Agricultural Economics

Advisor: Berihun Tefera Adugna (PhD)

July, 2024

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mrs. Tirngo Solomon Adamu entitled "Lime Technology Adoption and Its Determinants: the case of Debre Elias district, East Gojjam, Amhara, Ethiopia." We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agricultural Economics Department.

Board of Examiners

Name of External Examiner: Yalfal Temesgen (PhD) Signature __________Date: July 04, 2024

Name of Internal Examiner: Solomon Bizuayehu (PhD) Signature_______ Date July 04, 2024

Name of Chairman: Zemen Ayalew(PhD) Signature ________ Date__July /05/2024

DECLARATION

This is to certify that this thesis entitled "**Lime Technology Adoption and Its Determinants: The Case of Debre Elias District, East Gojjam, Amhara, Ethiopia,**" submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "**Agricultural Economics**" to the Graduate Program of College of Agriculture and Environme ntal Sciences, Department of Agricultural Economics, Bahir Dar University by **Tirngo Solomon Adamu** (**ID**. **No. 1401275**) is an authentic work carried out by her under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

Name of the Student:

Tirngo Solomon Adamu Signature Date 3/6/2024

Name of the advisor:

Berihun Tefera Adugna (PhD). Signature Date 3/6/2024

ACKNOWLEDGEMENT

I would like to thank my advisor Dr. Berihun Tefera Adugna for their valuable advice, insight and guidance starting from proposal development to the completion of the research work. I extend my thanks to all my families who inspired my confidence to finish my study. I am very grateful to Wolkite University for providing the chance to attend my study and recognizing the importance of this research and providing financial and material assistance, which managed to the implementation and completion of this study. I would like to thank all the farmers and development agents who have participated in this research and who offered their time for responding positively to the lengthy interview schedule. I would also like to thank the enumerators who have allowed the hardship and for filling the questions patiently. Finally, I would like to thank the department of agricultural economics instructors who provided me with the necessary knowledge and skills.

ABSTRACT

Agriculture is the pillar of Ethiopia's economy. However, it is constrained by soil acidity. Soil acidity is one of the problems that have resulted in low productivity in the country. Researchers and development practitioners tried to alleviate soil acidity and increase agricultural production. The adoption lime technology remains to be a promising strategy to reduce soil acidity, achieve food security and reduce poverty in Ethiopia. Despite the efforts to promote adoption in the country, the adoption rate has always been very low. So, it is essential to understand the determinants to the adoption of lime technologies. Thus, the primary goal of this study, which was carried out in the Debre Elias district, was to identify the basic factors influencing farmers' adoption and intensity of lime technology. *Data was collected from 366 households using a multi-stage sampling technique from three sample kebeles in Debre* Elias *district.* For the study, both primary and secondary data were employed. *Descriptive statistics such as percentage, mean, and standard deviation and inferential statistics such as independent t-tests and chi-square tests were used. Double hurdle model was also used to analyze the determinants of lime adoption intensity in the study. The result of the study in the probit model shows that farm size, training, land ownership, and extension service significantly and positively affected lime adoption participation. Whereas, distance to input market are significantly and negatively affected lime adoption participation. The truncated model result shows that the age of the household head and livestock holding significantly and positively affected lime adoption intensity. Farm size, extension service, and household size are significantly and negatively affected lime adoption intensity. Soil acidity treatment technologies adoption improvement requires training for households, increasing expert support, sharing experiences between adopters and non-adopters, and maximizing the adoption rate of lime by solving problems were some important ideas.*

Keywords: Lime Technology, Adoption, Probit model, Debre Elias, Ethiopia

TABLE OF CONTENTS

Contents **Pages**

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

LIST OF APPENDIXES

Appendixes **Pages**

ABBREVIATIONS AND ACRONYMS

AIC	Akaikes Information Criteria
CSA	Central Statically Agency
DA	Developmental Agent
DAP	Di-Ammonium Phosphate
ECP	Ethiopian Comprehensive Package
FTC	Farmers Training Center
GTP	Growth and Transformation Plan
HH	Household Head
KA	Kebeles Administration
ME	Man Equivalent
MOA	Ministry of Agriculture
MPP	Minimum Package Programs
NGO	Non-Governmental Organization
OLS	Ordinary Least Square
PSM	Propensity Score Matching
Qt/Ha	Quintal Per Hectare
SOM	Soil Organic Matter
SNNP	South Nation Nationality People
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor

CHAPTER 1. INTRODUCTION

1.1. Background of the Study

Agriculture is the main livelihood source of smallholder farmers who live in the developing world with the domination of traditional farming practices (Rehman *et. al*., 2019; Andani *et al*., 2020). Agriculture in Ethiopia is subsistence (CSA, 2022). In Ethiopia agriculture serves as a source of income and employment. It accounts for over 35.8% of national GDP and almost 90% of exports and 72.7% of employment (CIA, 2018).

Agriculture is the main economic sector which delivers sources of livelihoods to millions of people in the Amhara National Regional State. The sector creates 56% of the Region's GDP, while supporting 83% of its rural population. The existence of diverse agro ecological conditions makes the region suitable for the production of a large variety of crops and livestock resources. Crop and livestock production are the major subsectors contributing 68 and 20% of the Region's agricultural GDP, respectively (Ferede Setotaw *et al*., 2020).

Despite its diverse and significant contribution, still it is not well developed due to different constraints such as soil degradation, ineffective input management, limited application of new agricultural technologies, traditional farming methods, inadequate complementary services and, soil acidity (Temesgen Gebeyehu (2017). In Ethiopia, soil fertility issues are a major cause of food insecurity and poverty (Martey *et al*., 2019). Low fertility and ineffective soil management are the main obstacles to farmer's production in Ethiopia. To restore and sustain soil fertility, an increase in the use of inorganic fertilizer is necessary (Alhassan *et al*., 2020). But continues usage of inorganic/ mineral fertilizer, is not an environmental-friendly and sustainable practice as it can cause soil health degradations such as soil acidification, depletion of soil organic matter, increase greenhouse gas emissions, environmental contamination and a reduction in food safety (Mtangadura *et al*., 2017; Walling and Vaneeckhaute, 2020; Pandey and Diwan, 2021).

Soil acidity is one of the challenge for the farming community resulted in low productivity (Lakachew Ayenew, 2022; Workineh Ejigu *et al*., 2022; Hana Amare, 2023). Soil acidity is among the major constraints leading to nutrients deficiency, low crop yields and food insecurity in Ethiopia. Soil fertility decline due to soil acidity is one of the main constraints causing low crop yields in the Ethiopian highlands (Eyasu Elias *et al*., 2020). Soil acidity caused crop yield loss through reducing nutrient availabilities (Phosphorus, Potassium, Nitrogen, Calcium, and Magnesium) and increasing solubilizing aluminum or manganese to high concentration which causes phytotoxic. About 43% of Ethiopia's agricultural land is affected by soil acidity and 28% is estimated to be strongly acidic with soil pH ranging between 4.1 to 5.5 (Agegnehu, Getachew *et al*., 2019; 2021). Some technologies and practices have been recommended to reclaim soil acidity and upgrade the productivity of strongly acidic soils (Kiprotich *et al*.,2024). These involve the growing of acid-resistant plants, covering the surface with non-acidic soil, the application of organic fertilizers, and liming. Among these practices, liming and the application of organic fertilizers appear the best measures, because of their more persistent agronomic effects (Temesgen Desalegn *et al*.,2019; Warner *et al*., 2023).

Agricultural lime is a soil conditioner made from crushed limestone or dolomitic limestone with the primary active component of calcium carbonate. The application of agricultural lime is one of the main strategies for falling soil acidity and growing crop productivity. The amount of lime required for acidic soils depends on many factors, including existing soil pH, desired or target soil pH, and soil texture. For practical purposes the aim should be to keep the top-soil above pH 5.5 (Ritchey *et al*., 2016).

Consequently, Ethiopia has initiated an acid soil reclamation strategy that can address different segments along the agricultural lime value chain (Warner *et al.*, 2016; Tilahun Amede *et al*., 2019). The goal of the initiative is to provide enough lime to farmers at affordable prices in a timely and sustainable way. These initiatives include the production of lime in the upstream segment, transportation of lime including the last-mile distribution to farms in the mid-stream segment and the use of lime by farmers in the downstream segment. Several efforts have also been made to develop acid soil management packages, increase awareness through on-farm demonstrations and adoption of liming practices (Tilahun Amede *et al*., 2019). Despite these efforts, however, the actual lime application is negligible in the country. Previous studies Warner *et al.* (2016) showed that only 6% of planned agricultural lands received lime treatment, and only 7% of farmers used lime on their land in the first Growth and Transformation Plan (GTP I) period. The story was not different in GTP II. Only

36% of the planned cultivated lands were treated with agricultural lime in the GTP II period (MOA, 2020). In both GTP I and GTP II, only 2.4% of the severe acid soil area (3.7 million hectares) have been treated with lime.

A study demonstrated that liming increased the availability of both water and mineral nutrients for plant roots and reduced $Al_3^+$and Mn_2^+toxicity through decreasing their concentration (Holland *et al.*, 2018). Liming had been shown to increase crop yields (Goulding, 2016). However, liming impacts varies across different crops and soil types. Liming not only influenced crop quality but improved the development of crop disease resistance (Holland *et al.*, 2018). Agricultural production and productivity have stagnated or declined in many areas, a fact attributable to soil fertility depletion and decreasing soil pH. Soil degradation is recognized as a key factor underlying poor agricultural productivity in Ethiopia affecting the livelihoods of farmers and their environment (Amede and Whitbread, 2020).

Previous study showed that liming is the most effective method for alleviating soil acidity and enhancing nutrient availability (Liu *et al.*, 2020). Lime addition is used to increases soil pH, improves soil microbial activity, increases organic matter decomposition, releases essential nutrients such as Phosphorus, Potassium, Nitrogen, Calcium, Magnesium, and increases crop yields (Endalkachew Fekadu *et al.*, 2018; Asmamaw Demil *et al.*, 2020; Bossolani *et al.*, 2020).

Worsening soil acidity has dire consequences for low-income countries such as Ethiopia. Soil acidity results in loss of current as well as future income, and increased risk of crop failure, (Warner *et al.*, 2016). Therefore, it should increase the application of lime in order to decrease soil acidity to poverty reduction and food security improvement. Hence, to boost the production, the agricultural technology (lime) application need to increase. This in turn requires knowing the basic determinants of lime technology adoption and its intensity. Hence, this study attempted to explore the determinants of lime technology using the Debre Elias district as a case study.

1.2. Statement of the Problem

Agricultural production could be improved either by expanding the land coverage or by boosting the efficiency of agriculture. However, in the context of Ethiopia land is scarce and hence working on the extensive margin is especially challenging in Ethiopia. Therefore, boosting productivity through investing in agricultural technologies is the practical approach to accomplishing this goal (Mohammed *et al*., 2015). Through the diffusion of agricultural technologies, the government of Ethiopia has been striving to enhance agricultural output and solve major economic problems such as food price inflation, unemployment and food insecurity and its attempted to get done by an increasing application of agricultural technology (Assefa Admassie and Gezahegn Ayele, 2010).

Soil acidity is a widespread limitation to crop production in many parts of the world including sub-Saharan Africa (Workineh Ejigu *et al*., 2022). In Ethiopia, soil acidity is the major problem that is mostly observed in the soil of highlands receiving high rainfall (Wubayehu Kidanemariam, 2022).

The study area, Debre Elias district was suitable for the production of several crops. However, soil acidity and fertility depletion is the problem faced by smallholder farmers in the district. The report of Debre Elias Agricultural Office in 2023 showed that about 73% of Debre Elias cultivated land was affected by soil acidity and soil pH is less than 5.13. This problem is primarily resulted from continuous cultivation and crop removal of nutrients, leaching of ions due to high amount of rainfall, and continuous use of acidifying chemical fertilizers such as Di-Ammonium Phosphate (DAP). As a result, large area of the district has low soil fertility. The productivity of the district is declining year after year, and farmers are forced to expand their farm land to marginal areas and grazing lands.

A study was conducted to explain the factors affecting the adoption of lime technology in household level data using binary logistic regression model (Lakachew Ayenew, 2022). However, previous studies could not show intensity of lime adoption. This inspires me to conduct the study by using double hurdle model to show both adoption and intensity. In addition, decision to adoption affected by several factors which are different from place to place based on the difference in agro ecology and socio-economic situations. Still now, no or little empirical studies have been conducted on determinant of lime technology adoption and its intensity in the study area. To fill the above information, gap the main aim of this study is to identify factor affecting lime technology adoption and intensity in the study area.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study is to examine the determinant and intensity of adoption of lime in the study area

1.3.2. Specific objectives

- To identify the determinants of lime technology adoption in the study area
- To identify lime technology adoption intensity determinants for lime adopter farmers

1.4. Research Questions

- What are the factors affecting the adoption of lime in the study area?
- What are the determinants of lime adoption intensity in the study area?

1.5. Scope and Limitations of the Study

This study is focused on factor affected lime technology adoption Debre Elias District, East G ojjam Zone, Amhara Region, Ethiopia. In order to evaluate the gathered data effectively and maintain the scope within a stipulated time and financial limit, the study was conducted in one district consisting of 16 kebeles of which three kebeles were selected which emphasized on a limited number of households (366 HHS) and the determinant of adoption lime technology only taking into account. The other limitations of this study is: the use of a cross-sectional data rather than the possible panel data for some years.

1.6. Significance of the Study

Comprehensive understanding of farm adoption behavior is necessary for sustainable agriculture sector development. Adoption of modern technology like lime is an important agricultural policy issue. Therefore, the study is essential to understand the factors affecting the adoption of lime for increasing production in the study area. It also be important for policy makers and other stakeholders to achieve maximum production effort by decreasing soil acidity. Policy makers and implementers of different agricultural activities use the findings of the research for designing interventions. The study also provides a base for other studies; that focus on similar topic and issues related to the use of lime practices. It provides the bases for planning farmers training strategies for the adoption of new agricultural technologies.

1.7. Organization of the Study

The study is organized into five chapters. The first chapter consists of the introduction part. The second chapter presents literature reviews with theoretical reviews, empirical reviews, and conceptual framework subsections. The third chapter describes the methodology of the study which consists of descriptions of the study area, sampling procedure, and method of data collection and analysis. The fourth chapter deals with the result and discussion of the study. Finally, the conclusion and recommendations are presented in the fifth chapter.

CHAPTER 2. LITERATURE REVIEW

2.1. Definition of Terms and Concepts

Adoption: Adoption of an innovation within a social system takes place through its adoption by individuals or groups. According to Feder *et al.* (1985) adoption can be defined as the integration of agricultural innovations into traditional agricultural practices over a long period of time. However, Dasgupta (1989) argued that adoption is not a permanent behavior. This means that an individual may decide to stop using an innovation for a variety of personal, organizational and social reasons.

Rate of Adoption: Means the portion of the members of the society who start to use a new technology or innovation during a specific period of time.

The intensity of adoption: Is defined as the level of adoption of a given technology. The amount of lime adopted per hectare referred to as the intensity of adoption of the technologies.

Technology: According to Cantisani (2006) technology is the application of scientific knowle dge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of human environment. Technology as the means and methods of producing goods and services, including methods of organization as well as physical technique (Saron Mebratu and Tilahun Kenea, 2020).

Soil acidity: Soil acidity is a condition in which the soil pH is lower than a neutral pH (less than 7).

Lime: Lime is described as containing calcium or calcium magnesium compounds that can reduce the negative effects of soil acidity by altering soil acidity and increasing soil pH.

2.2. Theoretical Literature on Technology Adoption

2.2.1. Sources of technological change

Technology is about the relationship between input and output. Technology advancement makes it possible to create the same amount of output with a lower input or more output with fewer inputs (Colman and Young, 1989). According to Ellis (1993) agriculture sector implem ent new technologies which helps to enhance the agriculture productivity by improving the soil fertility or decrease the input utilization (labor, land, and capital). He further divided the source of technology adoption in to three major sources of technological changes in the agricultural sector.

The first source of technology was learned through experience. Explanation, use a given technology for long periods, they become experts on that technology and start to learn from its drawback and upgrade the technology. The second source of technological change is research and development which are divided into two: applied and basic or fundamental research categories. Applied research and development is designed to solve specific and well-defined practical problems, like improving agricultural crop production. On the other hand, fundamental research focuses on broader and more fundamental areas of understanding. Fundamental research may be mission oriented (e.g. fundamental biological research intended to provide a long-term knowledge base to fight cancer (Bentley *et al*., 2015). The last source of technology change is through importing and adapting from developed nations. They argued that this source of technological change has drawback, since new technology built based on the innovators country context, as a result new technology may not be suited for the importing country (Clarke *et al*., 2006).

2.2.2. Mode of technology adoption

Adoption of the whole package and sequential or stepwise adoption of the component package are the two mode of technology adoption. In the adoption of the full package program, farmers are expected to adopt a whole package like Ethiopian Comprehensive Package (ECP) and Minimum Package Programs (MPP). This program is highly advocated by technical scientists. Although the package program is highly promoted by the agricultural extension program, mostly such kind of adoption is costly and constrained by resource limitation in less developing countries (Ward *et al*., 2018). Contrary to this, Aldana *et al*. (2011) advocated that farmers prefer to adopt technology sequentially (i.e., farmers adopt only one type of technology initially and adopt others through time). As he elaborated farmers' prefer sequential adoption over whole package adoption due to the main reasons related to decreasing risk and uncertainty, lack of resources and lower institutional access of getting the whole package.

In addition to this, Ryan and Subrahmanyam (1975) pointed out that cash constraints are another factor which hinder farmers from adopting the whole package. According to him, rational farmers with financial constraints will use one technology and earn income from the use of this technology, then continue to use another technology according to the profit they make according to their combination of business conditions. This process will continue until the whole technology is fully adopted.

2.2.3. Theories of technological adoption and diffusion

According to; Ellis, (1993); Colman and Young, (1989) stated that the development of agriculture sector is highly depending on the successful innovation and their speed of adoption. Especially investment in knowledge in the form of science and technology is essential for the countries as well as world agriculture sector development. Many scholars accounted different factor for the lower success of agriculture sector but, lower rate of technology adoption is taken as the major reason for the lower rate of agricultural growth (Ellis, 1993; Colman and Young, 1989). As mentioned above, adoption is a decision to use or to continue using a given technology. It is quite known that adoption decision is not permanent rather it could change at any time due to a number of reasons (Mishra *et al*., 2015). The definition of adoption according to Fisher *et al*. (2000) the word adoption differs from diffusion. The former stand for an individual decision regarding a given technology while diffusion is a cumulative process by which new technologies are spread among users and measured in consecutive time periods.

The process of adopting technology has been researched for numerous years among various researchers. For example, Rogers' (2003) five-phase model or "the innovation-diffusion model" is the prominent model. According to this model, an individual pass through five stages from hearing about an innovation to adoption, and these stages are described as knowledge, persuasion, decision, implementation and evaluation stages. Knowledge is the first stage where an individual is aware about new technology and how to use it. In this stage critical question like why, what and how are always raised because individuals want to know more about technology. After an individual became aware about the technology he/she builds favorable or unfavorable attitude towards the new technology that forms the so-called persuasion. The third phase is the determination stage where an individual makes the choice to utilize or not to utilize a specific technology. The last stage is implementation where an individual puts the new technology into use, and at confirmation individuals evaluate the results of the new technology and the individual looks for support for his or her decision. More specifically, Rogers' (2003) five-stage model or "the innovation-diffusion model" is graphically depicted in the subsequent way.

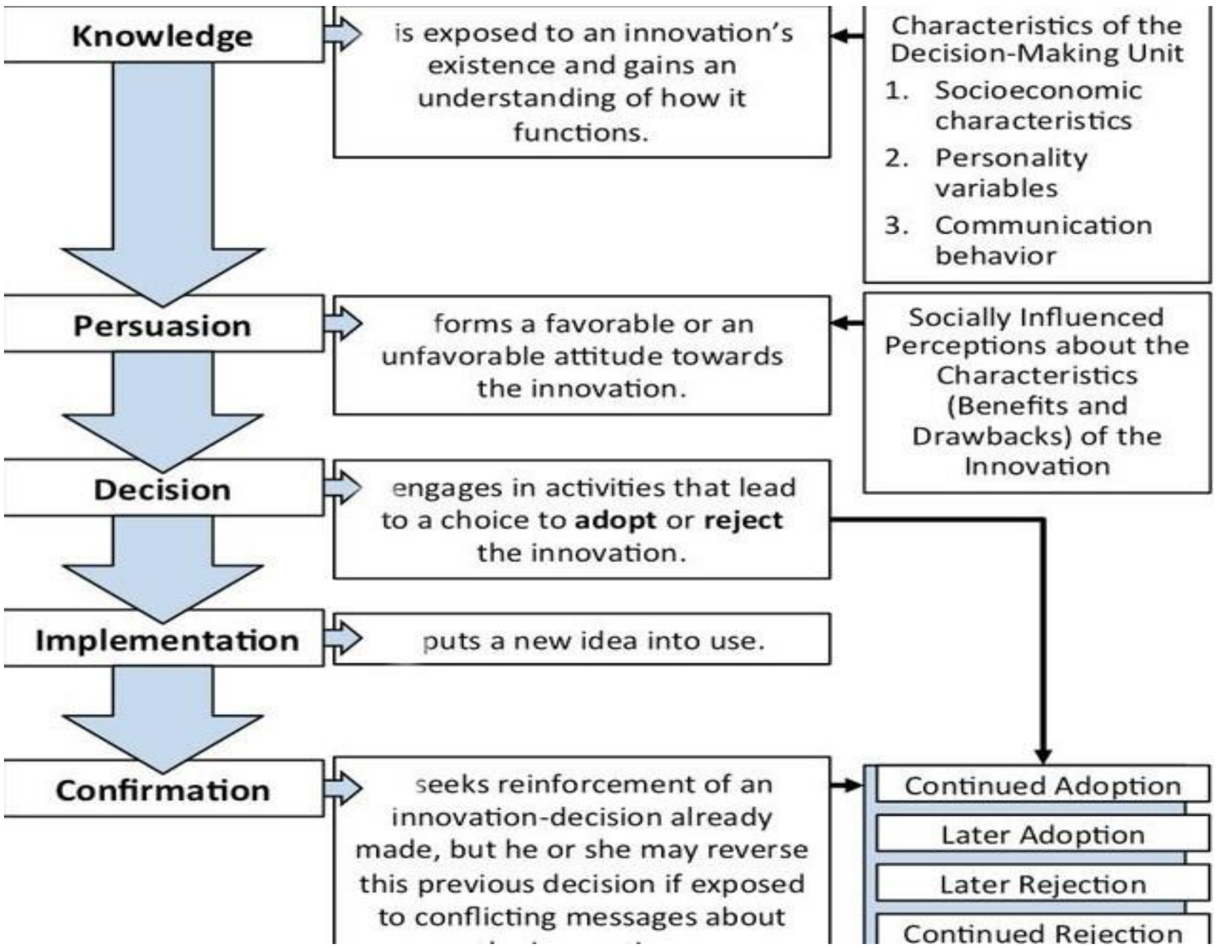

Figure 1: The five stages of innovation-decision process

Source: Rogers (2003)

2.2.4. Agricultural lime production in Ethiopia

Agricultural lime is produced by both private and public owned lime processing plants. However, both the public and private agricultural lime processing factories are operating below their potential capacity (Ali Oumer., *et al* 2023). Publicly-owned lime crushers (Guder, Dejen and Kella lime factories) were expected to function at maximum capacity. Nonetheless, because of restricted demand and other internal operational hurdles, the three factories are running at suboptimal capacity. Dashen cement factory has a large agricultural lime processing capacity but during 2021, it produced only 2% of its maximum capacity. The factory manufactured only the of lime agreed to it by the Amhara Provincial Government for the 2020/2021 manufacturing period. Likewise, Muger cement factory has the largest processing capacity but produced less than 1% of its maximum capacity due to a lack of ag-lime demand (Ali Oumer., *et al* 2023). Given the existing potentials in agricultural lime processing at the factories established mainly for lime crushing and the cement factories that could easily adjust and produce lime for agriculture, we (the authors) argue that producing a large quantity of agricultural lime should not be an issue in Ethiopia.

2.3. Empirical Review

2.3.1. Factors affecting the adoption of lime technology

The results of many studies (Challa, Merga, and Urgessa Tilahun 2014; Ayenew, Workineh 2020; Feyisa Bekele 2020) on technology adoption decision show that households' characteristics socio economic and institutional factors affect the adoption decision. These include variables like the sex of the household head, age of the household head, education level of the household head, family size, number of active laborers, land holdings, extension services, and credit affect adoption decision.

At the farm level, the economic rate at which farmers apply lime depends on net farm returns from lime application. These include expected yield, prices per unit of lime, transportation and application stages, as well as the expected number of years of enhanced productivity. All of these factors affect the adoption of lime. The application of lime is generally profitable, particularly when used in moderate amounts ranging from 2.0 to 2.2 t/ha in conjunction with other improved agricultural practices (organic fertilizers and high-yielding varieties) (Getachew Agegnehu *et al*., 2019).

Lakachew Ayenew (2022) showed that age, educational status, leadership status, economic level, family size, farm size, and access to extension expert contact had significant relationships with the adoption of agricultural lime inputs on acidic soils. On the other side, sex, marital status, and non-farm activities had no significant relationship with lime adoption.

The binary logistic regression result also indicated that educational status, leadership status, economic level, family size, and access to extension contact were positive determinants factors in lime adoption. Whereas, age of the household and farm size of the households were negative determinant factors in lime adoption.

Mesele Belay *et al*. (2022) uses a multinomial logit model to identify factors affecting the adoption decision of multiple agricultural technology include fertilizer, agricultural lime and improved seed. The result shows that farmers with more educational level, family size, off-farm participation, livestock, extension service, credit access, advisory service, and farmers closer to plot, all-weather road, and farmers with lower transfer income are more likely to adopt new or improved agricultural technology.

Kiprotich *et al*. (2024) use a Cragg's Double Hurdle model to determine the factors affecting adoption and adoption intensity of integrated soil fertility management technologies include lime among farmers. The results revealed that gender, dependents, farming goal for subsistence purpose, decision on information use, farm size, extension services, research awareness, and input access, significantly affected household decision on adoption of integrated soil fertility management technologies. On the other hand, sex of household head, farm size, main source of agricultural information and formal agricultural training had significant effect on adoption intensity of integrated soil fertility management technologies include lime.

Zelalem Yekoye (2016) studied farmers' responses to the application of different soil conservation measures in order to increase soil fertility. The results showed that there was a significant association between age, sex, household size, marital status, literacy status, and farm size, but household income had no significant association. Fanuel Laekemariam and Kibebew Kibret (2021) found that the result of the study showed that the extent and distribution of acidic soil, landscape characteristics, soil texture, land-use type, cropping intensity, continuous cropping, and farmer's perspective are factors that affect soil pH and lime adoption.

Abebaw Hailu and Girma Mulugeta (2022) studies on agricultural technology adoption used multinomial logit model. A multivariate logistic regression model showed that gender, age of the household, marital status, tropical livestock, education level of the household head, distance to market, extension contact, working household members, access to credit, off-farm activities participation, and land size were the determinants of modern agricultural technology adoption.

2.4. Soil Acidity and Acid Prone Areas in Ethiopia

In Ethiopia, large areas of the highlands in almost all provinces of the region, especially in the western part of the country, are affected by soil acidity. Predominantly, most parts of Wollega, Jimma and Ilubabor from the Oromia Region, and Gojjam from the Amhara Region are affected by soil acidity problem. These areas receive higher annual rainfall than other areas of the country (Eyasu Elias, 2017).

Soil acidification, which decreases the pH of the soil solution, is a complex problem resulting from the summation of natural and anthropogenic processes. Naturally, weathering of acidic parent materials, decomposition of organic matter, and deposition of atmospheric gases such as So_2, and HCl are natural causes (Goulding, 2016). Anthropogenic activities such as continuous application of acid-forming fertilizers including sulfur or ammonium salt and contact exchange among transferrable hydrogen on root surfaces and the bases in exchangeable form on soils, microbial production of nitric and sulfuric acids accelerate the process of soil acidification that could lead to increased soluble Al_3^+ concentrations in the soil solution.

2.4.1. Influence of soil acidity on yields of crops

Soil acidity is attributed to the abundance of mainly hydrogen and aluminum cations in soils at levels that interfere with the normal plant growth. Soil acidity has a negative effect on crop yields mainly through reduced phosphorus availability through iron and aluminum fixation (Okalebo, 2009). Excess aluminum ions, from soil acidity tend to accumulate in plant roots and there by prevent phosphorus translocation to the tops from the roots as evidenced by inhibition of root elongation and overall retarded crop development (Kanyanjua *et al*., 2002). One of the multiple characteristics of the acidic soils is the low volume of basic cations, such as calcium and magnesium (Opala, 2011). These elements are essential nutrients for plants in other words there must be enough quantity of each nutrient in order to assure the development and production of the crop (Haynes and Mokolobate, 2001).

2.4.2. Improved acid soil management practices

Enhancement of soil organic matter (SOM) is one of the key approaches of current agricultural research and development is to motivate farmers to make better use of organic resources to enhance fertility, alleviate elemental toxicity and protect the soil (Tilahun Amede *et al*., 2021). Green manuring, application of compost, lime application, and retention of crop residues are the key inputs to enhance soil organic matter and recycle nutrients to the soil. Studies have revealed that organic matter promotes microbial activity, improves soil structure, aeration, nutrient retention, and water holding capacity (Getachew Agegnehu and Tilahun Amede, 2017). Crop residues can reprocess nutrients removed from the soil by crops, while green manures contribute substantial amount of nitrogen to subsequent crops and at the same time protect the soil against erosion (Kumar and Sukul, 2020). Use of organic matter in the form of crop residues, green manures, compost could also reduce the effects of toxic elements by extracting them from the soil solution and incorporating them into organic compounds (Cornelissen *et al*., 2018).

Liming is one of the main interventions to rehabilitate acid soils with the application of lime or gypsum. Liming can shift soil acidity toward nearly neutral levels and improve availability of nutrients to plants (Carmeis Filho *et al*., 2017; Holland *et al*., 2018). Liming also stimulates microbial activities and enhances fixation and mineralization of nitrogen, there by legumes benefit highly from liming as aluminum toxicity and acidity suppresses microbial activities and nutrient cycling (Kunito *et al*., 2016). Liming materials are normally expressed in calcium carbonate ($CaCo_3$) (Yang *et al*., 2018).

2.5. Effects of Lime on Crop Productivity Improvement

Lime is used to increase in crop productivity and crop quality as compared to the unlimed treatment in crops (Fageria and Baligar, 2008; Abubakari *et al*., 2016). Long-term field trials proved that lime has an equalizing effect on annual and seasonal fluctuations regarding the availability of plant nutrients and thus the final crop yields. Better crop results were often obtained during the second year of lime application than the first year (Temesgen Desalegn *et al*., 2017).

Temesgen Desalegn *et al*. (2017) reported that the effect of lime on acid soil amelioration and barley grain yield was highest during the initial four years, but in the final year, grain yield declined substantially. This yield decrease in the final year indicates re-acidification of the soil. This might be due to lime-enhanced vegetative growth, thereby enabling the plant to bear a higher number of pods than the untreated soil condition and neutralizing soil acidity by lime, which in turn increases the availability of phosphorus for plant uptake through a reduction in its fixation on acid soils (Workneh Bekere *et al*., 2013).

Moreover, adoption of lime improved the plant's ability to absorb phosphorus by eliminating aluminum toxicity and enhanced the vegetative growth, which resulted in an increased yield. Liming of acid soil increased plant height, grain yields, and phosphorus uptake (Chimdi *et al*., 2012). This increase is related to the increase in soil fertility and the reduction of the toxic concentration of acidic cations. This, in turn, improves plant growth, which most likely resulted from the enhanced conditions for seedling growth, and also helps in raising the pH of the soil, which reduces the effect of acidity on the performance of the crop.

2.6. Conceptual Framework

From the previous studies, it is confirmed that the adoption of lime technology is expected to improve crop productivity with reduced soil acidity. At household level the adoption of lime technology is determined by different factors. These include demographic, socio-economic, and institutional factors. All these factors result in a farmer's forming positive or negative perceptions and attitudes towards lime technology. Those factors included in this study are shown in the conceptual framework in Figure 1 below:

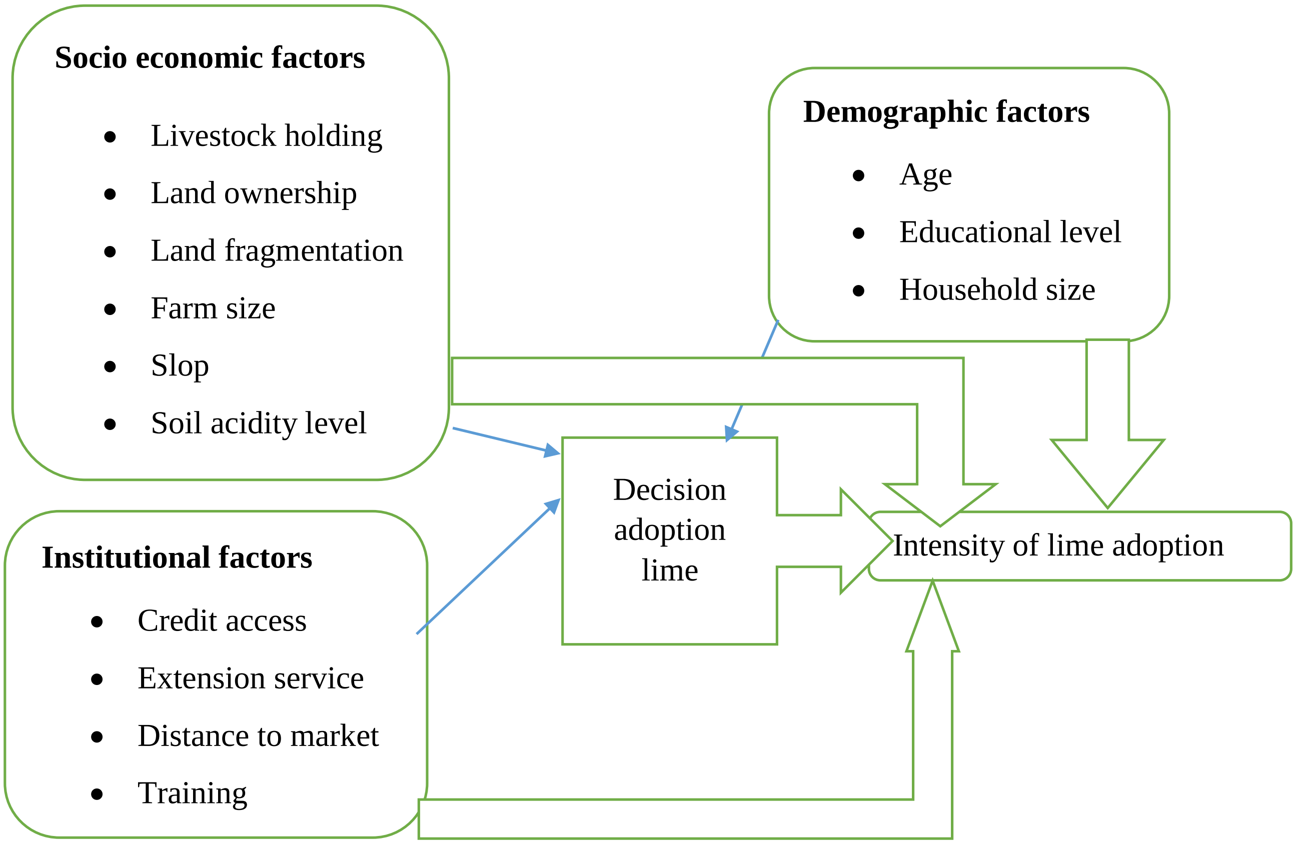

Figure 2: Conceptual framework of a study

Source: Own computation based on literature.

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Description of Study Area

This study was conducted in the Debre Elias district of East Gojjam Zone, Amhara Regional State, which is located around 340 km northwest of Addis Ababa, Ethiopia, and about 41 km northwest of Debre Markose town. It is bounded by the Abay River at the south and west, the west Gojjam Zone at the northwest, Machakele district at the north, and Guzamen district at the east. According to the Debre Elias district Agricultural Office (2023), there are 15 farmers' kebeles and one town administrative kebele. This district has a total population of 106,864, of whom 53,364 are men and 53,500 are women; 7,928, or 9.65%, are urban inhabitants. The district has a total area of 1,166 km^2, with a population density of 91.68 people per square kilometer.

The agro-ecology of the district is divided into two main parts, namely Woina Dega, which covers 86% of the total area. The remaining part, which is about 14% of the area, belongs to Kola. The mean annual temperature and mean annual rainfall are estimated to be 18–27°C and 1150 mm, respectively. In the study area, smallholder farmers are engaged in livestock rearing activities and crop production (mixed farming). Rain-fed agriculture is the dominant economic activity of the district, which serves as the livelihood base for smallholder farmers (Debre Elias district Agricultural Office 2023). Smallholder farmers produce both cash and food crops simultaneously. The altitude of the study area, which ranges from 800 to 2200 meters above sea level (Birara Endalew *et al*., 2020). Lime started in 2010 E.C. in the Debre Elias district and was adopted in Kebeles farmers training centers (FTC).

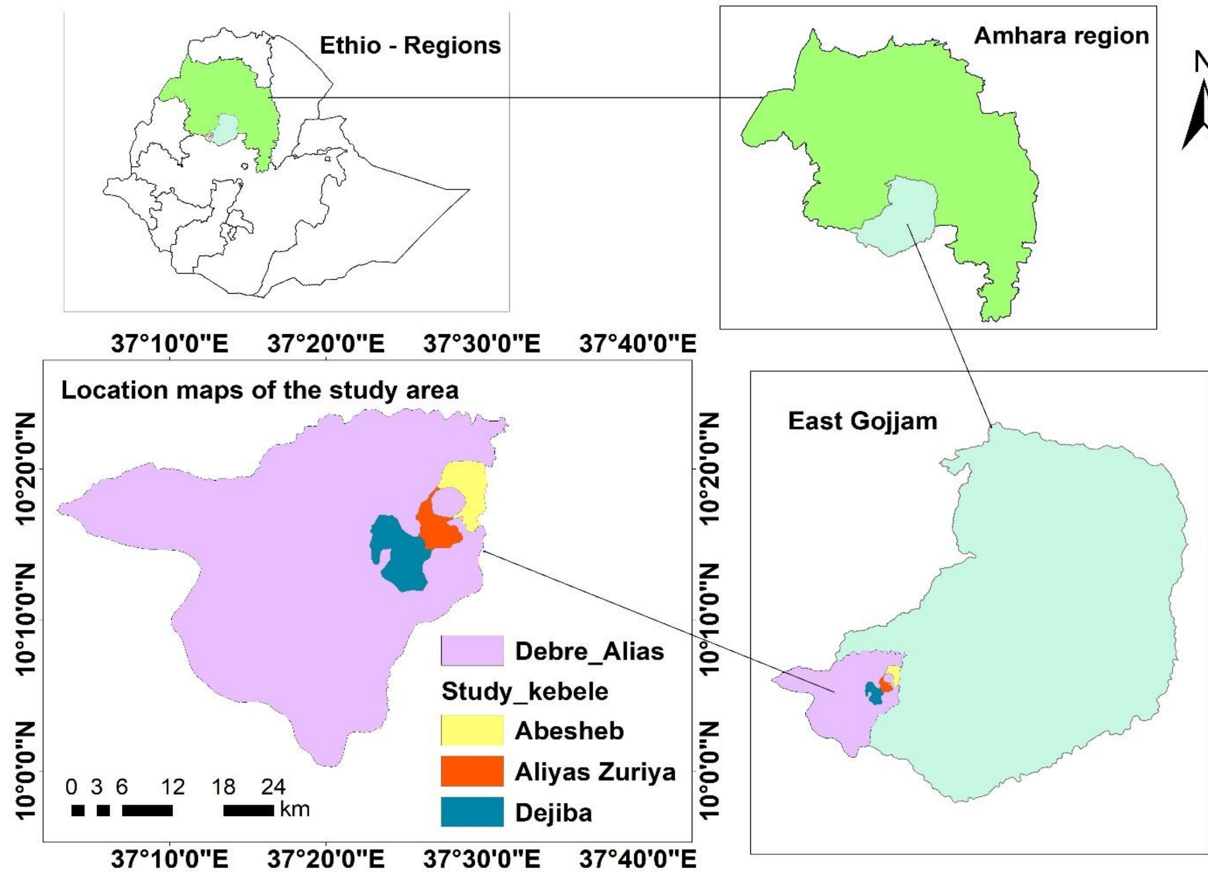

Figure 3: Study area map.

Source: Own constructed using Arc GIS.

3.2. Sampling Technique and Sample Size Determination

Sampling technique: The cross-sectional (survey) research design was applied in this study. The sampling technique plays a great role in the accuracy and validity of information. Multi-stage sampling techniques were employed to collect the data. The kebeles were the major target areas for sample selection. In the district, there are 16 kebeles, of which three (Degiba, Abesheb, and Aliyaszuriya) were selected purposively in the first stage. In the second stage, a list of all smallholder farmers in the three kebeles were stratified into two strata: lime adopters and non-adopters by using stratified sampling technique. In the third stage, 366 total sample households were selected using proportionate random sampling technique 134 from adopters and 232 from non-adopters of lime.

Sampling unit: For this study, different data were collected from the plot level by using a survey questionnaire. But the sampling unit was a household for analysis purposes.

Sampling frame: The sampling frame for this study is the list of households in the district. These households include both those who participated and did not participate in lime adoption.

Sample size determination: According to the data from Debre Elias Agricultural Office (2023) the total number of households of the district was 8,003. To determine the sample size by using Cochran (1977) sample size determination formula:

$$n = \frac{z^2(pq)}{e^2} \qquad n = \frac{1.96^2(0.50.5)}{0.05^2} = 385$$

where: n is the sample size, z is the selected critical value of desired confidence level (in our case 95% CI = 1.96, p is the estimated proportion of an attribute that is present in the population (in this study, since no estimated available we set at 50% or 0.05), q is equivalent to 1-p (1-0.5 = 0.5), and e is the desired level of precision (in this case 95% or 0.05). If the study population is small, the size can be reduced, Cochran said. To do this, he proposed the following statistical formula (Cochran, 1977).

$$n = \frac{n0}{1 + \frac{n0 - 1}{N}} \qquad n = \frac{385}{1 + \frac{385 - 1}{8{,}003}} = 366$$

where: n = sample size, n0 = 385 and N total population

Therefore, the total simple size required from adopters and non-adopters of respondents were 366 respondents were used to collect data.

Table 1: Sample size distribution from sampled kebeles

No	Kebeles	Number of total household	Number of sample household
1	Degiba	947	144
2	Abesheb	776	118
3	Aliyaszuriya	684	104
4	Total	2407	366

3.3. Data Sources, Types and Methods of Data Collected

Cross-sectional data was employed in order to collect both qualitative and quantitative data from primary and secondary sources.

A. Secondary data

The main sources of secondary data and information for this study were reports as well as records of published and unpublished documents of the Debre Elias Agriculture Office related to lime. Specifically, the price information for basic inputs were taken from Debre Elias Agriculture Office.

B. Primary data

The study principally employed primary data. A structured questionnaire (both closed-ended and open-ended questions) was prepared, pretested in the field, and adjusted accordingly. The questionnaire was translated from English to Amharic (the local language of the study area) to make the questions simple, clear, and understandable to the respondents, and implemented. Three enumerators with a B.Sc. degree were trained on how to administer the data collection work and could speak the local language. Finally, the data was collected from a sample of producers and interviews with district agricultural experts.

3.4. Methods of Data Analysis and Specification of Analytical Model

Descriptive and inferential statistics and the econometric model were actively employed for data analysis. Those analyses were performed using STATA software version 17.

3.4.1. Descriptive statistics

The descriptive analysis is essential in providing a better understanding of specific features of sample units. It allows comparing different categories of the sample unit for the desired characteristics by using tables, minimums, maximums, frequencies, percentages, means, and standard deviations. It explains and interprets the data obtained from sampled households' institutional, demographic, and socioeconomic characteristics. Appropriate statistical tests, such as the t-test (for continuous variables) and the Chi-square test (for discrete variables), were applied.

3.4.2. Econometrics model specification

Various econometric models have been employed to analyze the adoption and intensity behavior of farmers and identify the key factors in technology adoption. Some of the methods are tobit, double hurdle and Heckman (Intriligator, 1983). Based on the objectives of the study and the type of data available, the econometric model can be specified. The initial step involved conducting a diagnostic likelihood ratio test to estimate probit, truncated, and tobit regression models. The likelihood ratio test was used to compare the goodness of fit between the tobit and double-hurdle models (Greene 2002, 2012). According to Greene (2012), the likelihood ratio test for the tobit restriction can be carried out in the following manner:

$$\mathrm{Lg} = 2(\mathrm{LRprobit} + \mathrm{LRtrancated} - \mathrm{LRtobit})$$

where: Lg is the likelihood ratio test statistics, LRprobit + LRtruncated − LRtobit are the likelihood ratios of the three models. Because our estimated Lg was found to be statistically significant, we proceeded to employ the double hurdle model, which is a better alternative to fit the data. To choose between Cragg's double-hurdle or Heckman, we considered the inverse mills ratio of the Heckman estimate. The coefficient of the inverse Mills ratio, which is the error covariance, was found to be statistically insignificant, indicating the absence of selectivity bias, hence the choice of Cragg's double-hurdle for this study. Another statistical test used for comparing model is Akaikes Information Criteria (AIC) developed by (Akaike, 1974). Accordingly, the decision rule for this statistical test is that the model with the lowest AIC taken the best model among competing model.

$$AIC = -2(\text{loglikelihood}) + 2K$$

where: K is the number of estimated parameters included in the model, log likelihood of the model is derived by separately estimating each competing models. Therefore, to analyze our randomly selected sample data, the Double Hurdle method was implemented in this study.

Double Hurdle Model: The double-hurdle model was formulated by (Cragg, 1971). The model assumes that farming household heads make two sequential decisions with regard to the adoption and intensity of lime technology. The double hurdle model was used for the analysis with the assumption that the determinants of lime adoption and its intensity were independently determined. The individual's determinants of lime adoption are dichotomous, involving two mutually exclusive alternatives. The double hurdle model, on the other hand, allows for the adoption and level of decision to be used by different sets of factors and for the different factors to have different effects on each decision.

The study under take probit regression model to quantify the factors determines lime adopter and non-adopter among farmers in Debre Elias district. The fact that the dependent variable is a dichotomous justifies the use of a binary model (probit model). Accordingly, the dependent variable determinants of lime adoption assume only two values: one if the farmers adopt lime and zero if a farmer does not adopt. The first hurdle is the lime adoption equation estimated by using a probit model as described in the equation:

$$P_i^* = \beta_1 x_i + \varepsilon_i \sim N(0,1)$$

where, i = 1, 2…n

$p_i = 1 \ \ if \ p_i^* > 0$

$p_i = 0 \ \ if \ p_i^* \leq 0$

where, P_i^* is latent or unobserved lime adoption decision (1 if adopter and zero (0) otherwise), representing the individual's participation decision on lime adoption, p_i is observed lime adoption decision. To be specific, it takes 1 if a household adopt lime and is positive; and it is zero otherwise, x_i is a vector of independent variables (explanatory) variables that affect adoption of small holders lime on agriculture , β_1 is objective to be estimated (parameters to be estimated) is house hold to adopt lime, ε_i is an error term is normally distributed with mean zero (0), and standard deviation of 1, and captures all unmeasured variables. The second level of the analysis involved the truncated regression model for determination of factors that determine lime technology adoption intensity. Observations on positive and greater than the optimum lime adoption intensity are only used in the analysis:

$$Y_i^* = \beta x_i + \varepsilon_i \sim N(0, \sigma^2)$$

$$Y_i = Y_i^* > 0 \; and \; p_i = 1$$

$$Y_i = 0, \; if \; Y_i^* \leq 0$$

where: Y_i is the observed amount lime technology use which depends on the latent variable Y_i^* being greater than zero and conditional to the decision to use p_i lime, x_i is the vector of explanatory variables hypothesized to determine lime adoption intensity, Y_i^* is the latent or unobserved amount of lime adoption.

3.5. Definitions of the Variables and Working Hypothesis

One of the important parts of this section is to specify and hypothesize the dependent and explanatory variables that were used in the model. Regarding its definition, measurement, and hypotheses of variables that was used in our model, summarized.

3.5.1. Dependent variables

Lime adoption decision: The dependent variables in this study are lime adoption decision for the probit model, which is a dummy variable that takes the value 1 if the household adopts lime; otherwise, it takes the value zero (0).

Quantity of lime applied: It is a continuous variable that represents the outcome (dependent) variable for the double hurdle model. The intensity of lime adoption was measured amount of lime adopted in kg per total land in hectare. An adopter is defined as someone who uses at least one improved technology (Alemayehu Bashe *et al*., 2018). In this study, adopters are defined producers who adopted lime to the production and non-adopter farmers who have not applied lime to production. Intensity of adoption refers to an index indicating the farmer's level or extent of lime adoption. Extent of the respondent farmer has adopted the lime, was calculated by employing the following formula:

$$AI = \frac{\text{lime adopted in kg}}{\text{total land in hectare}}$$

3.5.2. Independent variables

The independent variables are identified from previous studies and the nature of the study area. These variables are expected to result in variations in the use of lime in agricultural production by farmers in the study area. The independent variables are as follows:

Age of household head (AGEHH): This variable is continuous and is measured in years from birth. It is assumed that as farmer age increases, the probability of adoption is expected to decrease because, as farmer age increases, the farmer is expected to become more conservative (Aman Dassa, 2022). In other word with age farmers can get experience in adoption of lime it gets anticipating participation decision to lime adoption. Therefore, it was hypothesized that it affects adoption negatively or positively with the increase in the age of farmers.

Education status (EDU): It is often assumed that educated farmers are better able to process information and search for appropriate technologies to alleviate their production constraints. Geofer (2004) stated that education enhances farmers' willingness to adopt even new management practices by improving their managerial capacity. It is treated as a categorical variable to see its influence on the adoption of lime technology. It is measured as zero (0), if the farmer is illiterate 1, if the farmer can read and write only, and 2, if the farmer attended formal education. Therefore, education was hypostatized to affect lime adoption positively.

Household size (HH SIZ): Continuous variable representing the number of people living in a house as parents, children, and relatives under one household leader in terms of ME. It is expected that as the size of the household increases, the adoption of new technology was increase. This implies that farmers with large households was certainly generate more income through large-scale production of improved technologies (lime) using household labor (Lakachew Ayenew, 2022). Contradict Mengistu Ketema and Degefu Kebede (2017) as the size of the household increases, the adoption of new technology decreases due to the limited capacity to afford technology given the extra living expenses required for the household members. It measures man-equivalent. Therefore, it was hypothesizing that household size and adoption of lime are expected to be positively or negatively related.

Access to credit (PRA CR): It requires credit to procure complementary inputs to maximize their benefits. Farmers without cash and no practice of credit was find it very difficult to attain and use new technologies. Credit facilities emerged as a significant positive influence for small landholders as they released financial constraints, enabling them to procure more agricultural technologies. It is measured as a binary variable: 1, if the farmer gets credit, and zero (0), otherwise (Pandey and Diwan, 2021). It was hypothesized to affect the adoption of lime technologies positively.

Farm size (FA SIZ): Refers to household total land size owned. Therefore, farm size is an important variable. It is a continuous variable measured in hectares. Increase land size leads to decrease lime adoption due to limited supply of labor, especially during the peak time of lime adoption, and moreover, lime is a labor-intensive technology. It was hypothesized to have a negative effect on the adoption of lime.

Extension service (EXT SERV): An extension service agent refers to the involvement of agricultural experts in developing the general cognitive abilities of farmers via training, experience sharing, and practical help. It is expected that farmers who have contact with development agents are more likely to adopt agricultural inputs like lime than farmers who have no contact with development agents. This is a dummy variable measured as 1 if the farmer has access to extension service about lime adoption and zero (0), otherwise. Contact with extension agents increases the adoption of lime (Lakachew Ayenew, 2022). Therefore, extension service was hypostatized to affect lime adoption positively.

Participation in training: Training is one of the means by which farmers acquire new knowledge and skills, and it is measured in terms of participation in the training program and treated as 1, for farmers who participated in the training of lime zero (0), otherwise. Hence, participation in training influences farmers' adoption behavior. It was hypothesized to affect adoption of the practice positively.

Livestock holding (LIV HOL): Is a continuous variable that represents the livestock holding of a household measured in a tropical livestock unit (TLU). This could be due to the fact that households with a larger number of livestock holdings minimize the capital constraints to purchase agricultural inputs as well as their risk-taking behavior to use technologies like lime

(Mengistu Ketema and Degefu Kebede, 2017). It was hypothesized to affect adoption of the practice positively.

Distance to input market (MRK DIS): Is another important factor influencing the adoption of agricultural technology. The household is far from market centers, making it difficult to access information about technology and prices (Negase Tamirat, 2021). Therefore, it was hypothesized to affect adoption of the practice negatively.

Perception of soil acidity level (PER ACID): Show that farmers' perceptions of the acidity of their land have a significant bearing on their decisions to use lime technology. Farmers who perceive that their land is affected by acidity require more lime technology (Vanlauwe *et al*., 2011). It is a dummy variable 1 if acidity high zero (0), otherwise. Therefore, it was hypothesized to affect adoption of the practice positively.

Dominant slope: Slope is related to soil erosion and deposition processes. Fanuel Laekemaria m and Kibebew Kibret (2021) mentioned a decreasing trend in soil pH with increasing slope classes. It is a dummy variable and measured 1 if slop is flat zero (0), otherwise. Therefore, it was hypothesized to be positively related to the adoption of lime technology.

Number of framing plots managed (PLOTNO): This is defined as the total number of plot that the farmer has manage during the production season. A plot is a piece of land used for different purposes. Increase land fragmentation leads to decrease lime adoption. It is a discrete variable measured in number. Therefore, it hypothesized that lime adoption would be negative. It is contradict with the finding of Kerale Kasaso (2015).

Land ownership (LNDOWNER): This is a dummy variable measured as 1 if the farm or land for the production is owned and zero (0), otherwise. Farmers give priority, especially during peak periods of farming, to their own land, as they would acquire the whole output that would be obtained from the land. Therefore, it was hypothesized to affect adoption of the practice positively.

Table 2: Summary of definition and measurements of variables and its hypothesis

Description of variables	Definition and measurements	Expected sign
Dependent variable		
▪ Lime adoption decision	Dummy 1 if the household is adopt 0, otherwise	
▪ Outcome variable		
▪ Quantity of lime used	Continuous measured in adoption index	
Independent variables		
▪ Age of household head	Continuous measured in year	+/-ve
▪ Education Status	Categorical If 0ilitrate, 1 read and write,2 formal educ	+ve
▪ Household size	Continuous measured in man equivalent	+-ve
▪ Practice of credit	1 gets credit 0, otherwise	+ve
▪ Farm size	Continuous measured in hectare	-ve
▪ Extension service	Dummy 1 if access 0, otherwise	+ve
▪ Participation in training	Dummy 1 participated 0, otherwise	+ve
▪ Livestock holding	Continuous measured in total livestock unit (TLU)	+ve
▪ Distance to input market	Continuous measured in minute	-ve
▪ Perception of soil acidity level	Dummy 1 high 0, otherwise	+ve
▪ Dominant slope	Dummy 1 flat 0, otherwise	+ve
▪ Number of framing plots	Discrete measured in number	-ve
▪ Land ownership	Dummy 1 owned 0, otherwise	+ve

CHAPTER 4. RESULT AND DISCUSSION

This chapter presents results and discussion in two main sections, descriptive results and econometrics result.

4.1. Distribution of Respondents in Their Respective Kebeles

The numbers of respondents involved in the study from Degiba, Abesheb and Aliyaszuriya kebeles were 144, 118 and 104, and share 39.34%, 32.24% and 28.42% of the total respondents, respectively (Table 3).

Table 3: Distribution of respondents in their respective Kebeles

Kebeles	Adopters		Non-adopters		Total	
	Frequency	%	Frequency	%	Frequency	%
Degiba	25	18.66	119	51.29	144	39.34
Abesheb	61	45.52	57	24.57	118	32.24
Aliyaszuriya	48	35.82	56	24.14	104	28.42
Total	134	100.00	232	100.00	366	100.00

4.2. Households Characteristics by Descriptive and Inferential Statistics

Age of household head: The average age of the whole sampled household heads was 45.44 years, with the minimum and maximum ages of 23 and 80 years, respectively. The average age of adopters and non-adopters were 43.89 and 46.34, respectively. The independent t-test result implied that there was a significant mean difference between the adopters and non-adopters in relation to age at $p<0.1$ significance level ($t = 1.9$, $p = 0.06$).

Household size: The average household size of the whole sampled households was 2.99, with a minimum and maximum of 1.1 and 8.1, respectively. The average household size of adopters and non-adopters was 2.94 and 3.02, respectively. The independent t-test result implied that there was no statistically significant difference between adopters and non-adopters in household size ($t = 0.6$, $p = 0.56$).

Livestock holding: In the study area, farmers rear animals for different purposes and serve as a source of income, food, or draft power. Basically, cattle, small ruminants, horse donkeys, and poultry are the major groups of livestock at Debre Elias district. The result in Table 4 reveals that the average number of livestock owned by the overall respondent in the study area was 4.90, whereas the mean number of livestock owned by adopters and non-adopters was 5.00 and 4.84 in TLU, respectively. As a survey year result indicated, there was no statistically significant difference between adopters and non-adopters in livestock holding ($t = -0.65$, $p = 0.52$). In order to make comparison easy, depend on (Strock *et al.,* 1991) the livestock population of the sampled household converted to TLU.

Farm size: The result in Table 4 reveals that the mean farm size of total respondents was 1.48. The average farm size of adopters and non-adopters was 1.74 and 1.33 hectares, respectively. In other words, adopters have significantly higher farm sizes than non-adopters of lime. The independent t-test result implied that there was a significant mean difference between the adopters and non-adopters in relation to farm size at $p<0.01$ significance level ($t = -9$, and $p = 0.00$).

Number of framing plots managed: The result in Table 4 reveals that the mean plot number of total respondents was 4.64. The average plot number of adopters and non-adopters was 4.60 and 4.66, respectively. As a survey year result indicated, there was no statistically significant difference between adopters and non-adopters in number of plots ($t = 0.40$, $p = 0.68$).

Perception of soil acidity levels: The data collected at the plot level shows that the response of the respondent is different in their plot. For this reason, the soil acidity level changed in percent. The acidity level of the district is 73% (District Agriculture Bureau, 2023). Due to this, medium acidity is considered a high acidity level. The result in Table 4 reveals that the mean acidity level of total respondents was 88.30% high and 11.70% low. But the average acidity level of adopters was 96.27% high and 3.73% low, and the average acidity level of non-adopters was 83.69% high and 16.31% low. The independent t-test result implied that there was a significant mean difference between the adopters and non-adopters in relation to acidity level at $p<0.01$ significance level ($t = -4.30$, $p = 0.00$).

Land ownership: The data collected at the plot level showed that the respondent's response differed depending on their plot, resulting in a change in land ownership percentage. The result in Table 4 reveals that the mean land ownership of total respondents was 80.60% owned and 19.40% not owned (rented). But the average land ownership of adopters was

86.63% owned and 13.37% not owned, and the average land ownership of non-adopters was 77.12% owned and 22.88% not owned. The independent t-test result implied that there was a significant mean difference between the adopters and non-adopters in relation to land ownership at $p<0.01$ significance level ($t = 2.75$, $p = 0.01$).

Distance to input market: The result in Table 4 reveals that the mean distance from the input market of the total respondents was 79.65. But the average distance of adopters and non-adopters was 74.93 and 82.37, respectively. The independent t-test result implied that there was a significant mean difference between the adopters and non-adopters in relation to distance to input market at the $p<0.1$ significance level ($t = 1.85$, $p = 0.06$).

Table 4: Summary of continuous demographic, socio-economic and institutional variables

Variable	Adopters		Non-adopter		Total				T
	Mean	Sd	Mean	Sd	Min.	Max.	Mean	Sd	
Age of household head	43.89	11.35	46.34	12.34	23	80	45.44	12.03	1.9*
Household size	5.74	1.34	5.68	1.21	2	11	5.70	1.25	
Man equivalent	2.94	1.25	3.02	1.25	1.1	8.1	2.99	1.24	0.6NS
Livestock holding	5.00	2.49	4.84	2.22	0	18.34	4.90	2.32	-0.65NS
Farm size	1.74	0.63	1.33	0.49	0.63	3.75	1.48	0.58	-8.9***
Number of plots	4.60	1.11	4.66	1.32	2	11	4.64	1.24	0.4NS
Acidity level	96.27	15.78	83.69	31.73	0	100	88.30	27.65	-4.3***
Land ownership	86.63	26.66	77.12	34.86	0	100	80.60	32.39	-2.75***
Distance to input Market	74.93	33.98	82.37	38.55	10	285	79.65	37.07	1.85*

Note: ***, ** and * = at $p<0.01$, $p<0.05$ and $p<0.1$ significance probability level respectively, Sd = Standard deviation, Max. = Maximum, Min. = Minimum, T = T-value, NS = No significant. Source: Survey result, 2023

Education status: The survey results in Table 5 show that out of the total respondents 42.08%, the household heads were illiterate, 18.58% could only read and write, and 39.34% attended formal education. In addition to this, 28.36% and 50.00% of adopter and non-adopter sample respondents were illiterate, 21.64% and 16.81% of the adopter and non-adopters could read and write, and 50.00% and 33.19% of the adopter and non-adopters attended formal education, respectively. The Chi-square test showed that there was a significant association between the adopters and non-adopters in terms of education status at $P<0.01$ significance level.

Practice of credit: The survey results in Table 5 show that out of the total respondents, 51.91% used credit and 48.09% didn't use credit. In addition to this, 67.91% and 42.67% of adopter and non-adopter sample respondents used credit, and 32.09% and 57.33% of adopters and non-adopters did not use credit, respectively. The Chi-square test shows that there was a significant association between the adopters and non-adopters in terms of practice credit at $p<0.01$ significance level.

Participation in training program: The survey results in Table 5 show that of the total respondents, 47.81% attended a training program on lime adoption, and 52.19% didn't attend a training program on lime adoption. In addition to this, 98.51% and 18.53% of adopter and non-adopter sample respondents attended training, and 1.49% and 81.47% of adopter and non-adopter sample respondents had not attended training, respectively. The Chi-square test shows that there was a significant association between the adopters and non-adopters in terms of attended training at $p<0.01$ significance level.

Extension service: The survey results indicated in Table 5 show that of the total respondents, 50.30% made contact with development agents, and 49.70% didn't get support and had not made contact with development agents. In addition to this, 98.50% and 22.40% of adopter and non-adopter sample households had access to extension experts' support and contact, respectively, and 1.50% and 77.60% of adopter and non-adopter households had not had contact with development agents respectively. The Chi-square test shows that there was a significant association between the adopters and non-adopters in terms of extension at $p<0.01$ significance level. Out of the total adopters only 25% have extension service and used recommended rate of lime and the remaining 75% have access to extension service and use below the recommended rate

Dominant slope: The survey results indicated in Table 5 show that of the total respondents, 69.10% were non-flat and 30.90% were flat. In addition to this, 83.60% and 60.80% of adopter and non-adopter sample households were non-flat, and 16.40% and 39.20% of adopter and non-adopter households were flat, respectively. The Chi-square test shows that there was a significant association between the adopters and non-adopters in terms of dominant slop at p<0.01 significance level.

Table 5: Summary of categorical variables

Variable		Adopters		Non-adopters		Total		Chi^2
		Freq.	%	Freq.	%	Freq.	%	
Education status	Illiterate	38	28.40	116	50.00	154	42.10	16.62***
	Read and write	29	21.60	39	16.80	68	18.60	
	Formal education	67	50.00	77	33.20	144	39.30	
Training	No	2	1.50	189	81.50	191	52.20	217.72***
	Yes	132	98.50	43	18.50	175	47.80	
Credit	No	43	32.10	133	57.30	176	48.10	21.67***
	Yes	91	67.90	99	42.70	190	51.90	
Extension	No	2	1.50	180	77.60	182	49.70	196.74***
	Yes	132	98.50	52	22.40	184	50.30	
Slop	Non flat	112	83.60	141	60.80	253	69.10	20.70 ***
	Flat	22	16.40	91	39.20	113	30.90	

Note: *** = p<0.01 significance probability level, and Freq. = Frequency.

Source: Survey result, 2023

4.3. History of Lime Technology Adoption

Information gathered from key informant interviews revealed that lime production in Dejen started in 2010 E.C. in the study area and was adopted in Kebeles farmers training centers (FTC). The government gave lime without payment as a trial and to begin the extension service in 2012 in Yejube, Motta, Machakele, Gozzamen and Enebse sar midr districts of East Gojjam. But after a year, the government delivered to farmers at a price of 80 birr per quintal via FTCs. The recommended lime per unit of land (ha) in the study area was 2000 kg (20 quintals). Lime is sown in two ways: after plowing the land before two months of sowing, the crop uses the full recommended lime (20 quintals), and during sowing, the crop uses one-fourth (1/4) of the recommended lime. In this district, there is an absence of machines for application of lime, which are not available in the local market. To solve this problem, they are currently using their hands to sow lime. Once applied the lime have been considerable effect to minimize soil acidity problem for four years.

4.4. Status of Adoption of Lime Technology

In this study, adoption of lime technology refers to the continued use of lime on an area of land. Here, the respondents who have used the study area during the survey year and in any two of the years before the survey year of this study are considered adopters. Farmers who never adopted lime are categorized as non-adopters. Accordingly, the study reveals that out of the total respondents, 134 (36.61%) household heads adopted lime technology, whereas 232 (63.39%) of the sample household's non-adopters. This indicated that the majority of the respondents were non-adopters of lime technology. The main reason for not adopting lime technology is price increments from year to year. Farmers in the study area have used about 49% of the recommended rate of lime where the recommended rate is 2000 kg/ ha. The result depicts that use levels of lime in general falls below the recommended rates.

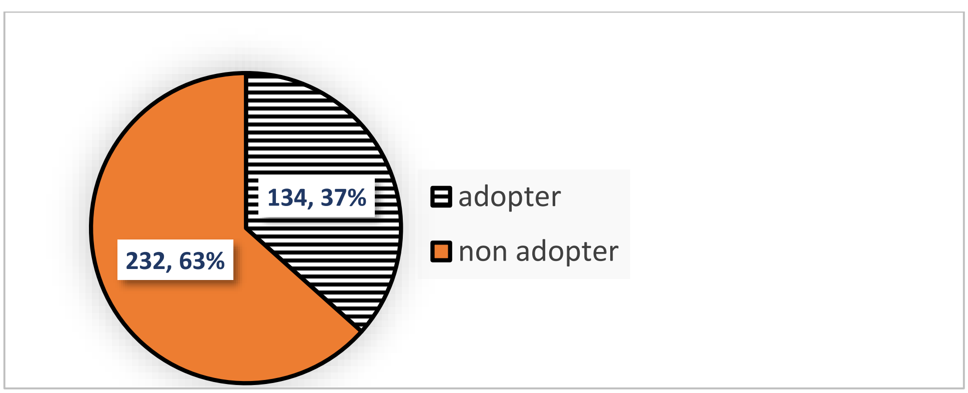

Figure 4: Status of adoption of lime technology.

Source: Survey result, 2023

4.5. Current State of Farmers in Utilizing Lime

The survey results in Table 6 show that from the total respondents, 2.19% adopted lime at a decreasing rate, 15.30% started adoption recently, 63.39% have a plan to adopt, and 19.13% adopted with an increasing rate. This indicates that most of the respondents have a plan to adopt lime technology. Therefore, the government needs additional efforts to supply and distribute lime.

Table 6: Current state of farmers in utilizing lime

	Current state of farmers in utilizing lime	Frequency	%
Adopters	Adopting with decreasing rate	8	2.19
	Started adoption recently	56	15.30
	Adoption with increasing rate	70	19.13
Non adopters	Have plan to adopt	232	63.39
Total		366	100

Source: Survey result, 2023

4.6. Production and Productivity

The result in Table 7 shows that the mean yield obtained from adopters was 37.82 qt/ha. However, the mean yield obtained from non-adopters was 28.89 qt/ha. The average product obtained from adopters and non- adopters was 30.66 and 15.79 quintals, respectively. The independent t-test result implies that there was a significant mean difference between the adopters and non-adopters in relation to production and productivity at the $p<0.01$ significance level ($t = -17.8$, $p = 0.00$) and ($t = -4.85$, $p = 0.00$), respectively. Compared to non-adopter adopters, they produce a high quantity in the study area.

Table 7: Descriptive of production and productivity for adoption of lime

Variables	Adopters		Non-adopters		Total		t-test
	Mean	Sd	Mean	Sd	Mean	Sd	
Total production	30.66	9.59	15.79	6.35	21.23	10.51	-17.8***
Productivity in qt/ha	37.82	15.63	28.89	17.73	32.16	17.51	-4.85***

Note: Sd =Standard deviation

Source: Survey result, 2023

4.7. Econometric Model Results

Before running the econometric analysis, the data was tested against different econometric pro blems.

Multicollinearity: The multicollinearity test for all continuous variables was also done using the variance inflation factor (VIF). Specific to dummy variables, the contingency coefficient was calculated to test for the existence of a multicollinearity problem. The issue arises when one or more independent variables are linearly dependent on each other. The existence of multicollinearity might cause the estimated regression coefficients to have the wrong signs, which might lead to the wrong conclusion. VIF can be defined as:

$$\mathrm{VIF(Xi)} = \frac{1}{1 - \mathrm{Ri}^2}$$

where: Ri^2 is the square of multiple correlation coefficients that results when one explanatory variable (X_i) is regressed against all other explanatory variables. The larger the value of VIF (X_i), the more collinear the variable X_i is. As a rule of thumb, if the VIF of a variable exceeds 10, there is a multicollinearity problem. Likewise, to test the multicollinearity problem of dummy variables, contingency coefficients were used. When the value of the correlation coefficient is > 0.8, there is a multicollinearity problem. The regression and correlation matrix results showed that multicollinearity didn't exist among variables.

Heteroscedasticity: One of the assumptions in regression analysis is that the errors (u_i) exhibit homoscedasticity, meaning they have a constant variance σ^2. If the errors do not have a constant variance, we say they are heteroscedastic. However, the estimated parameters of a regression in which heteroscedasticity is present are consistent, though they are inefficient. Accordingly, the data was checked for heteroscedasticity using the Breusch-Pagan test, and the result showed that there was no serious problem of heteroscedasticity. Therefore, the analysis included all the relevant variables.

4.7.1. Factors determining lime technology adoption

A result from the first stage of the double hurdle model has been estimated by maximum likelihood. The overall model is significant at 1% ($p<0.01$) significant levels (Prob > Chi^2 = 0.00), as indicated by the log pseudo likelihood value of 346.67, and this suggests that the explanatory variables included in the models are meaningful and relevant. The results from the first stage of the double hurdle model indicated that the statistically significant factors determining the adoption of lime technology were age, farm size, land ownership, training, distance to the input market, and extension. The marginal effects of the probit model show changes in the probability of adoption of lime technology for an additional unit increase in the independent or decision variables.

Farm size: The analysis using the probit model in Table 8 revealed that farm size has a significant positive impact on the participation of adopting lime technology at the $p<0.01$ level of significance. Larger farm sizes were associated with more diversified income compared to smaller farms, allowing households to have greater financial resources to invest in lime technology. The marginal effect analysis showed that for every one-hectare increase in farm size, the probability of adopting lime technology increased by 8%, holding all other variables constant (Abebaw Hailu and Girma Mulugeta, 2022).

Land ownership: Ownership of land has a significant and positive impact on the adoption of lime technology, as expected. The probit model analysis demonstrated a significant and positive relationship between land ownership and the participation of adopting lime technology at the $p<0.01$ significance level. The marginal effect result indicated that with each additional percentage of land ownership, the probability of adopting lime technology increased by 12.4%. This indicates that farmers who owned land were more inclined to adopt lime technology compared to those who rent land. The preference for their own land, particularly during peak farming periods, stems from the fact that they would benefit entirely from the output produced on their owned land.

Access to training: The model results shows that access to farmer training has a positive and significant effect on households' adoption at the $p<0.01$ significance level. The marginal effect of the model results shows that the probability of households' adoption increased by 21% when households had access to training, while keeping other factors constant. This result is consistent with the findings of Biniam Teshome *et al*. (2019).

Distance to input market: The coefficients of distance from the market have a negative and significant effect on the adoption of lime technology. The negative association indicates that people living far from markets are less likely to adopt lime technology. The reasoning is that farmers' proximity to roads and all-weather markets is important for the timely delivery of inputs and output processing and leads to a reduction in input market transportation costs. The marginal effect indicates that as the distance to the market increases by one minute, the probability of adopting lime technology decreases by 0.07%. This result is in line with the findings of Abebaw Hailu and Girma Mulugeta (2022).

Access to extension: The probit model result shows that access to extension was found to have a positive and significant influence on the participation of lime technology adoption at p<0.01 level of significance. The marginal effect of the model results shows that the probability of households' adoption increased by 23.3% when households had access to extensions, while keeping other factors. The result satisfies the a priori expectation because the extension agent visit has the tendency to create more awareness and better information among the farming household heads on the importance of lime technology. This result is in line with the findings of Akpan *et al*. (2012); Abebaw Hailu and Girma Mulugeta (2022).

Table 8: Determinants of lime adoption participation decision: probit model result

Variables	Coefficient	Std. err	dy/dx	P>|z|
Educational status	-0.019	0.150	-0.002	0.895
Age of household head	-0.025	0.016	-0.003	0.117
Livestock holding	-0.039	0.059	-0.006	0.501
Number of framing plots	-0.113	0.134	-0.011	0.399
Farm size	0.810***	0.270	0.081	0.003
Slop	-0.145	0.313	-0.015	0.642
Land owner	1.240***	0.386	0.124	0.001
Acidity level	0.762	0.575	0.077	0.185
Training	2.087***	0.414	0.210	0.000
Distance to input market	-0.008**	0.0037	-0.0007	0.033
Credit	-0.036	0.297	-0.004	0.904
Extension	2.325***	0.456	0.233	0.000
Household size	-0.100	0.138	-0.010	0.467
Cons	-3.533	1.150		0.002
Number of obs. = 366				
Log likelihood = 346.67				
Pseudo R^2 = 0.7210				
LR Chi^2 (13) = 364.10				
Prob. > Chi^2 = 0.0000				

Note: *** and ** at 1% ($p<0.01$), and 5% ($p<0.05$) significance probability level respectively, Std. err = standard error, and dy/dx = marginal effect.

Source: Survey result, 2023

4.7.2. Factors determining lime technology adoption intensity

According to the second stage of the double hurdle, the model Chi-square test indicates that the overall goodness of fit is significant at $p<0.01$ significance levels. This indicated that jointly explanatory variables included in the model explained lime technology adoption intensity. The results from the second stage of the double hurdle model indicated that the statistically significant factors determining lime technology adoption intensity were age of households, TLU, plot number, farm size, extension, and family size (man equivalent).

Age of the household head: Truncated model result shows that the age of the household head was found to have a positive and significant influence with lime adoption intensity at $p<0.01$ significance level. An increase in the age of small holders by one year increases lime adoption intensity by 15.81 kg/ha, keeping other variables constant. This suggests that elderly smallholder farmers regularly adhere to the guidance of agricultural experts and embrace agricultural technology. This aligns with the research done by Aman Dassa (2022).

Livestock holding: The model results show that ownership of livestock was found to have a positive and significant effect on the intensity of lime adoption at the $p<0.05$ level of significance. As household livestock ownership increases by one TLU, it increases lime adoption intensity by 30.98 kg/ha, keeping other variables constant. Livestock ownership is considered an asset that could be used either in the production process or it could be exchanged for cash (particularly small ruminants) for the purchase of inputs whenever the need arose. Moreover, livestock is considered a sign of wealth and increases the availability of cash for adopting technologies. The result is consistent with the findings of Mengistu Ketema and Degefu Kebede (2017); Mideksa Dabessa *et al*. (2021).

Farm size: The model result show that farm size was found to have a negative and significant effect on the intensity of lime adoption at the $p<0.01$ significant level. As the household head farm size increases by one hectare, it decreases lime adoption intensity by 442.2 kg/ha, keeping other variables constant. In other words, farmers have a limited supply of labor, especially during the peak time of lime adoption, and moreover, lime is a labor-intensive technology (this leads to poor management with an increase in farm size). The result is consistent with the findings of Mengistu Ketema and Degefu Kebede (2017) and contradict with the findings of Efa Gobena (2016).

Extension service: The model result show that extension service was found to have a negative and significant effect on the intensity of lime adoption at $p<0.05$ level significant. As farmers got extensions, it decreased lime technology adoption intensity by 512.82 kg/ha. The reason for this the first: the quality of the extension service was poor. Particularly extension agents are actively involved in other political activities besides their duty. The second reason farmers have not properly applied the service that they got, or the service they got is not related to lime technology adoption. In other words, extension services offered to farmers not be compatible with agro ecology. Moreover, extension services in the study area have not effective. The result is consistent with the findings of Tadie Mirie *et al*. (2019) and contradict with the finding of Adisalem Samuel and Dinku Amare (2021).

Household size: Based on the truncated model result, household size in terms of man equival ent was found to have negative and significant effect on lime adoption intensity at $p<0.01$ level of significance. An increase family in ME decreases lime adoption intensity by 171.35 kg/ha. Hence, given the higher opportunity cost of labor in the study area, application of more labor for other technologies (like organic fertilizer preparation) affects lime adoption intensity negatively. As the size of the household increases, lime adoption intensity decreases due to the limited capacity to afford technology given the extra living expenses required for the household members. The result is consistent with the findings of Mengistu Ketema and Degefu Kebede (2017), and contradict with the finding of Nigus Gurmis *et al*. (2019).

Table 9: Determinants of lime adoption intensity: truncated model result

Variables	Coefficient	Std. err	P>|z|
Educational status	-10.17	37.92	0.789
Age of household head	15.81***	4.776	0.001
TLU	30.98**	14.48	0.032
Number of framing plots	-51.17	39.56	0.196
Farm size	-442.2 ***	78.26	0.000
Slop	140.69	85.73	0.101
Land owner	114.54	123.23	0.353
Acidity level	229.82	207.74	0.269
Training	53.015	255.16	0.835
Distance to input market	1.277	1.007	0.205
Credit	40.489	78.266	0.605
Extension	-512.82**	259.680	0.048
Household size	-171.35***	41.810	0.000
Cons	1076.58***	394.182	0.006

Number of obs. = 366

Truncated observation = 232

Un truncated observation = 134

Log pseudo likelihood = -916.26859

Prob > Chi2 = 0.000

Wald Chi^2 (13) = 58.94

Note: *** and** at 1% (P<0.01) and 5% (P<0.05) significance probability level respectively, and Std. err = standard error.

Source: Survey result, 2023

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Soil acidity is a serious problem in Ethiopia. Decreasing soil acidity of land, plays great role in increasing productivity by given agricultural technologies (lime). This study aimed to identify factors affecting lime adoption and its intensity by using survey data from Debre Elias district. Multi stage sampling technique was used to select sample kebeles and sample households. 366 sample households were the source of primary data and district and kebele level reports, and other secondary data source were used to collect the data. Based on qualitative and quantitative analysis, it can be concluded that the adoption of lime in the study area is low.

Double hurdle model were used to analyze the determinants of households 'lime adoption participation decision and adoption intensity. Out of the total sample households, 134 households, about 36.6 %, were adopters and the remaining 232 households were non-adopters of lime technology. The study also identified the average production difference between adopters and non-adopters. The mean product obtained from adopters and non-adopters was 30.66 and 15.79 quintals respectively. The mean yield obtained from adopters and non-adopters was 37.82 and 28.89 qt/ha.

This study concludes that lime adoption is a vital means for productivity improvement. According to the results from the first stage of the double hurdle model indicated that, out of thirteen explanatory variables, farm size, land ownership, training, and extension were positively and statistically significant determinant factors, whereas distance from the input market determined lime adoption negatively and statistically. A second stage of the double hurdle model result indicated that age of the household head and livestock holding were positively and statistically significant determinant factors, whereas farm size, extension service, and household size were negatively and significantly indicated to decrease lime adoption intensity.

5.2. Recommendations

Based on the results of this research, the following core points are presented as recommendati on in order to improve the adoption of lime technology: It is better to encourage lime adoption because the results of this study confirmed that application of lime increases production substantially.

- The findings of this study revealed that livestock are important farm assets that help farmers adopt lime or make sufficient input purchases. It is, therefore, important that more attention be given to farmers' financial empowerment including income from the livestock sector by improvement of genetic, feed, and management conditions.
- Those farmers who had a large farm adopted lime in a better way, but the amount of lime adoption decreased compared to those who had a small farm. Therefore, governmental organizations, and agricultural extension must be avoiding constraints that hinder farmers use maximum amounts of lime technology.
- Training was found to positively and significantly affect lime adoption participation. Therefore, it recommends that governmental organizations, agricultural extension agencies, and NGO's strengthen their efforts to provide short-term training programs to equip farmers with the necessary knowledge, skills, and attitudes relevant for the adoption of lime.
- Attention has to be given to farmers who have rented land to empower them and participate in lime technology adoption through delivering agricultural input credits to increase lime adoption.
- Concerning distance from the market, the government should give more attention to improving the existing market centers in the study area by building roads and providing good means of transport for farmers.
- The government and concerned bodies must use additional efforts to upgrade the skills and knowledge of the extension agents, as well as ensure timely dissemination of modern technological inputs and practices related to lime technology.
- This study dealt with the adoption and its determinants of lime technology in agriculture production. For future research, it would be better to study the impact of lime technology adoption.

REFERENCES

Abebaw Hailu and Girma Mulugeta. (2022). Determinants of modern agricultural technology adoption for teff production: The case of Minjar Shenkora district, north Shewa zone, Amhara region, Ethiopia. *Advances in Agriculture*, 2022:1–12. https://doi.org/10.1155/2022/2384345.

Abubakari, F., Tetteh, F., Abubakari, F., Tuffour, H., and Aduwu, A. (2016). Strategies for improving nodulation and nitrogen fixation of leguminous crops to enhance production in smallholder farming systems. *Journal of Global Agriculture and Ecology*, 4(4): 185–190.

Adisalem Samuel, and Dinku Amare. (2021). Determinants of inorganic fertilizer use by smallholder farmers in South Wollo and Oromia special administrative zones, Ethiopia. *Journal of Agricultural Extension*, 25(4): 101–108. https://doi.org/10.4314/jae.v25i4.11.

Akaike H. (1974). A new look at the statistical model identification. In: IRRR transactions on automatic control. 19(6): 716–723. https://doi.org/10.1109/TAC.1974.1100705.

Alemayehu Bashe, Zekarias Bassa, and Seifu Tyohannis. (2018). The determinants of probability in improved forage technology adoption in Wolaita zone: The case of Sodo Zuria district, Southern Nations and Nationalities Peoples state of Ethiopia. *Open Access Journal of Science*, 2(4): 228–231. https://doi.org/10.15406/oajs.2018.02.00078.

Alhassan, A., Abdul Hamid, B., and Gazali, I. (2020). Fertilizer subsidy policy and smallholder farmers crop productivity: The case of maize production in North-Eastern Ghana. *Journal of Agricultural Extension and Rural Development*, 12(2): 18–25. http://www.academicjournals.org/JAERD.

Ali Oumer, Samuel Diro, Geremew Taye, Tadele Mamo, Moti Jaleta. (2023). Agricultural lime value chain efficiency for reducing soil acidity in Ethiopia. *Soil Security*, *11*, 100092.

Aman Dassa. (2022). *Determinants of Inorganic Fertilizer Use Intensity on Cereal Crop among Smallholder Farmers:* The Case of Toke Kutaye District, West Shewa Zone, Oromia National Regional State, Ambo University Ethiopia. *Research Square.*1–22. https://doi.org/10.21203/rs.3.rs-1256471/v1.

Agegnehu Getachew, Chilot Yirga, and Teklu Erkossa. (2019). Soil acidity management. *Ethi opian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia*, *21*.

Agegnehu Getachew, Tilahun Amede, Teklu Erkossa, Chilot Yirga, Carol Henry, Robert Tyler, Matthew G. Nosworthy, Sheleme Beyene, and Gudeta W. Sileshi. (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review. *Acta Agriculturae Scandinavica, Section B — Soil and Plant Sci.*, 71 (9): 852–869. https://doi.org/10.1080/09064710.2021.1954239

Asmamaw Demil, Tadele Amare, Yihenew Awoke, Assefa Derebe and Tilahun Adera. (2020). Bridging the yield gaps of bread wheat at a scale through an innovative method of lime application in the acidic soils of Northwestern Ethiopia. *Cogent Food and Agriculture*, 6(1): 1–24. https://doi.org/10.1080/23311932.2020.1803578.

Assefa Admassie and Gezahegn Ayele. (2010). Adoption of improved technology in Ethiopia. *Ethiopian Journal of Economics*, 19(1): 155 179. https://doi.org 10.4314/eje. v19i1.71 416.

Ayenew, Workineh, Tayech Lakew, and Ehite Haile Kristos. (2020). Agricultural technology adoption and its impact on smallholder farmers' welfare in Ethiopia. *African Journal of Agricultural Research*, 15(3): 431-445.

Bentley, P., Gulbrandsen, M., and Kyvik, S. (2015). The relationship between basic and applied research in universities. *Higher Education*, 70(4): 689–709. https://doi.org/10.1007/s10734-015-9861-2

Biniam Teshome, Rahmeto Negash and Amanuel Shewa. (2019). Determinants of adoption of improved Jalenea potato variety: The case of Chencha district, Southern Ethiopia. *Jour nal of Development and Agricultural Economics*, 11(7): 170-185. http://www.academicjournals.org/JDAE.

Bossolani, J., Crusciol, C., Merloti, L., Moretti, L., Costa, N., Tsai, S., and Kuramae, E. (2020). Long-term lime and gypsum amendment increase nitrogen fixation and decrease nitrification and denitrification gene abundances in the rhizosphere and soil in a tropical no-till intercropping system. *Geoderma*, 375(1): 1–12. https://doi.org/10.1016/j.geoderma.2020.114476.

Carmeis Filho, A., Penn, C., Crusciol, C., and Calonego, J. (2017). Lime and phosphogypsum impacts on soil organic matter pools in a tropical Oxisol under long-term no-till conditions. Agriculture, Ecosystems and Environment, 241: 11–23. https://doi.org/10.1016/j.agee.2017.02.027.

Challa, Merga, and Urgessa Tilahun. (2014). Determinants and impacts of modern agricultura l technology adoption in west Wollega: the case of Gulliso district. *Journal of Biology, Agriculture and Healthcare*, 4(20): 63-77.

Centeral Statically Agency. (2022). Agricultural sample survey report on area and production of major crops (Private peasant holdings, Meher season 2021/22 (2014 E.C.)). The FDRE statistical service, Volume I.

Central Intelligence Agency. (2018). The work of a nation, Ethiopian economy profile. CIA World Fact Book, January 20, 2018.

Clarke, L., Weyant, J., and Birky, A. (2006). On the sources of technological change: Assessing the evidence. *Energy Economics*, 28(5–6): 579–595. https://doi.org/10.1016/j.eneco.2006.05.004.

Cochran Wiliam G. (1977) Sampling Techniques, Third Edition, by John Wiley and Sons, Published in Canada.

Colman, D. and Young, T. (1989). *Principles of agricultural economics: Markets and prices in less developed countries.* Cambridge University Press,1–62.

Cornelissen, G., Nurida, N., Hale, S., Martinsen, V., Silvani, L., and Mulder, J. (2018). Fading positive effect of biochar on crop yield and soil acidity during five growth seasons in an Indonesian Ultisol. *Science of the Total Environment*, 634: 561–568. https://doi.org/10.1016/j.scitotenv.2018.03.380.

Cragg, J. (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica: Journal of the Econometric Society*, 39 (5): 829–844. https://doi.org/10.2307/1909582.

Dasgupta, S. (1989). *Diffusion of agricultural innovations in village India*. Wiley Eastern. pp 183.

Degefu Kebede, Mengistu Ketema, Nigussie Dechassa, Feyisa Hundessa. (2017). Determinants of adoption of wheat production technology package by smallholder farmers: Evidences from eastern Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology*, 5(3): 267–274. https://doi.org/10.24925/turjaf.v5i3.267-274.1041.

Efa Gobena. (2016). Determinants of market participation and intensity of marketed surplus of teff producers in Bacho and Dawo districts of Oromia State, Ethiopia. *Forthcoming : Agricultural Economics*, 5(2): 20-320. http://academeresearchjournals.org/journal/jaed.

Ellis, F. (1993). *Peasant economics: Farm households in agrarian development*. 2nd Edition, Cambridge University Press, 1–136.

Endalkachew Fekadu, Kibebew Kibret, Bobe Bedadi, Asmare Melese, and Birru Yitaferu. (2018). Organic and inorganic amendments on soil chemical properties at different period of incubation of acidic soil. *Eurasian Journal of Soil Science*, 7(3): 273–283. https://doi.org/10.18393/ejss.435095.

Eyasu Elias, Beyene Teklu and Tewodros Tefera. (2020). Effect of blended fertilizer applicati on on bread wheat yield, agronomic efficiency and profitability on Nitisols of Southern Ethiopia. *South African Journal of Plant and Soil*, 37(4): 292–299. https://doi.org/10.1080/02571862.2020.1791982.

Eyasu Elias, Okoth PF, Smaling EMA (2019). Explaining bread wheat (*Triticum aestivum* L.) yield differences by soil properties and fertilizer rates in the highlands of Ethiopia. *Geoderma*, 339(1):126–133. https://doi.org/10.1016/j.geoderma.2018.12.020.

Eyasu Elias. (2017). Characteristics of Nitisols profiles as affected by land use type and slope class in some Ethiopian highlands. *Environmental Systems Research*, 6(20): 1–15. https://doi.org/10.1186/s40068-017-0097-2.

Fageria K. and Baligar C. (2008). *Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production*. *Advances in agronomy*, 99: 345-399. http://dx.doi.org/10.1016/S0065-2113(08)00407-0.

Fanuel Laekemariam, and Kibebew Kibret. (2021). Extent, Distribution, and Causes of Soil Acidity under Subsistence Farming System and Lime Recommendation: The Case in Wolaita, Southern Ethiopia. *Applied and Environmental Soil Science*, 2021: 1-9. https://doi.org/10.1155/2021/5556563.

Feder, G., Just, R., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, 33(2): 255–298. https://www.jstor.org/stable/1153228.

Ferede Setotaw, Chilot Yirga, Aemiro Kehaliew, Getachew Agegnehu, and Tesfahun Alemu. (2020). *Farming systems characterization and analysis in East Gojjam zone: Implications for research and development (R&D) interventions*. Ethiopian Institute of Agricultural Research.

Feyisa Bekele. (2020). Determinants of agricultural technology adoption in Ethiopia: A meta-analysis. *Cogent food and agriculture*, 6(1): 1855817.

Getachew Agegnehu and Tilahun Amede. (2017). Integrated soil fertility and plant nutrient management in tropical agro-ecosystems: A review. Pedosphere, 27: 662–680. https://doi.org/10.1016/S1002-0160(17)60382-5.

Getachew Agegnehu, Chilot Yirga, and Teklu Erkossa. (2019). *Soil Acidity Management*.1–65. http://www.eiar.gov.et.

Goulding, K. (2016). Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. *Soil Use and Management*, 32(3): 390–399. https://doi.org/10.1111/sum.12270.

Geofer. (2004). Soil conservation Activities in India. New Delhi, Tana McGraw-Hill publishing Company Limited.

Greene W. (2002). Econometric Analysis (5th ed ed). Prentice Hall.

Greene W. (2012). Econometric Analysis. (7th. ed.). Prentice Hall. Inc.

Hana Amare. (2023). Lime Technology Practices for Mitigating Soil Acidity in Ethiopia: A Review. *International Journal of Environmental Monitoring and Analysis*, 11(6): 114-120. https://doi.org/10.11648/j.ijema.20231106.11.

Haynes, R., and Mokolobate, M. (2001). Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: A critical review of the phenomenon and the mechanisms involved. *Nutrient Cycling in Agroecosystems*, 59(1): 47–63. https://doi.org/10.1023/A:1009823600950.

Intriligator M. (1983). Economic and econometrics models. Handb Econ 1:181–221. https://doi.org/10.1016/S1573-4412(83)01007-7.

Kanyanjua, S., Ireri, L., Wambua, S.and Nandwa, S. (2002). Acidic soils in Kenya: Constraint s and remedial options. 11: 1 27. http://repository.seku.ac.ke/handle/123456789/4313.

Kerale Kasaso (2015) 'Household Food Security Status and Its Determinants in Rural Konso district, Segen Area Peoples' Zone, Southern Ethiopia MSc Thesis KARALE'.

Kiprotich, S., Mogaka, H., Ndirangu, S., and Onyari, C. (2024). Determinants of adoption and adoption intensity of integrated soil fertility management technologies among sorghum farmers in Upper Eastern Kenya. *Soil Use and Management*, *40*(1): e12958.

Kumar, S. and Sukul, P. (2020). Green manuring and its role in soil health management. *Soil Health,* 59: 219–241. https://doi.org/10.1007/978-3-030-44364-1_13.

Kunito, T., Isomura, I., Sumi, H., Park, H., Toda, H., Otsuka, S., Nagaoka, K., Saeki, K., and Senoo, K. (2016). Aluminum and acidity suppress microbial activity and biomass in acidic forest soils. *Soil Biology and Biochemistry*, 97: 23–30. https://doi.org/10.1016/j.soilbio.2016.02.019.

Lakachew Ayenew. (2022). Determinants Affecting Lime Technology Adoption on Agricultu ral Land in Senan District, North West Ethiopia. *International Journal of Environmental Chemistry*, 6(1): 28-35. https://doi.org/10.11648/j.ijec.20220601.13.

Martey, E., Kuwornu, J., and Adjebeng-Danquah, J. (2019). Estimating the effect of mineral fertilizer use on Land productivity and income: Evidence from Ghana. *Land Use Policy*, 85: 463-475. https://doi.org/10.1016/j.landusepol.2019.04.027.

Mesele Belay, Abebaw Hailu and Getamesay Bekele. (2022) Determinants of multiple agricultural technology adoption: evidence from rural Amhara region, Ethiopia, *Cogent Economics and Finance*, 10(1): 2058189, DOI: 10.1080/23322039.2022.2058 189

Mengistu Ketema, and Degefu Kebede. (2017). Adoption intensity of inorganic fertilizers in maize production: Empirical evidence from smallholder farmers in eastern Ethiopia. *Journal of Agricultural Science*, 9(5): 124–132. https://doi.org/10.5539/jas.v9n5p124.

Mideksa Dabessa, Moti Jaleta, and Fikadu Mitiku. (2021). Determinants and profitability of inorganic fertilizer use in smallholder maize production in Ethiopia. *Cogent Food and Agriculture*, 7(1): 1–20. https://doi.org/10.1080/23311932.2021.1911046.

Ministry of Agriculture, (2020). Acid Soil Development. Ag-lime Feasibility Study.

Mohammed, A., Jaleta, M. and Berg, E. (2015). Adoption of multiple sustainable agricultural practices and its impact on household income: Evidence from southern Ethiopia. *International Journal of Agriculture and Biosciences*, 4(5): 196–205. www.ijagbio.com.

Mtangadura, T., Mtambanengwe, F., Nezomba, H., Rurinda, J., and Mapfumo, P. (2017). Why organic resources and current fertilizer formulations in Southern Africa cannot sustain maize productivity: Evidence from a long-term experiment in Zimbabwe. *PLoS One*, 12(8): 1–23. https://doi.org/10.1371/journal.pone.0182840.

Negase Tamirat. (2021). Adoption of Chemical Fertilizer Technology and Household Food Security, in Southern Ethiopia, in Case of Soro District in Hadiya Zone. *Journal of Agronomy, Technology and Engineering Management,* 4(1): 558-576.

Nigus Gurmis, Bosena Tegegne, Alelign Ademe. (2019). Determinants of smallholder teff producer farmers market participation in Merhabete District, Amhara Region, Ethiopia. *International Journal of Agricultural Economics,* 4(4), 135. https://doi.org/10.11648/j.ijae.20190404.11.

Okalebo, J. (2009). Recognizing the Constraint of Soil Fertility Depletion and Technologies to Reverse it in Kenya Agriculture. Inaugural Lecture 6 Series No.1, Moi University, Kenya. *International Journal of Plant and Soil Science1,* 3(3): 1-12. https://doi.org/10.9734/IJPSS/2016/13494.

Opala, P. (2011). Comparative effects of lime and organic materials on selected soil chemical properties and nutrient uptake by maize in an acid soil. *Archives of Applied Science Research*, 3(1): 96–107. https://repository.maseno.ac.ke/handle/123456789/2015.

Pandey, C. and Diwan, H. (2021). Assessing fertilizer use behavior for environmental manage ment and sustainability: A quantitative study in agriculturally intensive regions of Uttar Pradesh, India. *Environment, Development and Sustainability*, 23(4): 5822–5845. https://doi.org/10.1007/s10668-020-00848-1.

Rehman, A., Chandio, A., Hussain, I., and Jingdong, L. (2019). Fertilizer consumption, water availability and credit distribution: major factors affecting agricultural productivity in Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, 18(3): 269-274.

Ritchey, K., Feldhake, C., Clark, R., and Sousa, D. (1995). Improved water and nutrient uptake from subsurface layers of gypsum-amended soils. In Agricultural utilization of urban and industrial by-products. ASA Spec. Publ. 58. ASA, Madison, WI, pp. 157–181. https://doi.org/10.2134/asaspecpub58.c8.

Ryan, J. and Subrahmanyam, K. (1975). Package of Practices Approach in Adoption of High-Yielding Varieties an Appraisal. *Economic and Political Weekly*, 10(52): A101–A110. https://www.jstor.org/stable/40738467.

Samuel Gebreselassie, Mekbib Haile, and Matthias Kalkuhl. (2017). *The wheat sector in Ethiopia: Current status and key challenges for future value chain development*, 160. http://dx.doi.org/10.2139/ssrn.3013041.

Saron Mebratu, and Tilahun Kenea. (2020). *Review on Adoption of selected Improved Agricultural Technology on Production of Teff in Ethiopia*. *Academic Research Journal of Agricultural Science and Research,* 8(3): 234 243. http://dx.doi.org 10.146 62/ARJASR2020.047.

Tadie Mirie, Abebe Birara and Taye Melese. (2019). Technical efficiency of smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia. *Journal of Economic Structures*, 8(1), 1-18. https://doi.org/10.1186/s40008-019-0150-6.

Temesgen Desalegn, Getachew Alemu, Ayalew Adella, Tolessa Debele and Julián Gonzalo. (2017). Effect of lime and phosphorus fertilizer on acid soils and barley (*Hordeum vulgare* L.) performance in the central highlands of Ethiopia. *Experimental Agriculture*, 53(3): 432–444. https://doi.org/10.1017/S0014479716000491.

Temesgen Desalegn, Dejene Abera, Solomon Endris, Wondimu Tolcha and Tilahun Hordofa., 2019. In: Proceedings of the Natural Resources Management Research completed Research activities Workshop. Addis Ababa, Ethiopia, eds. November 25- 26at EIAR-HQ.

Temesgen Gebeyehu. (2017). Poverty, peasantry and agriculture in Ethiopia. *Annals of Agrarian Science*, *15*(3): 420-430.

Tilahun Amede, Schulz, S., Warner, J., Solomon, Tefera. (2019). Managing Acid Soils for Reclaiming Livelihoods in Ethiopia. ICRISAT-GIZ, Addis Ababa. Managing acid soils Ethiopia 02 May 2019 low.pdf (icrisat.org) (accessed 25 March 2022).

Tilahun Amede, Gizachew Legesse, Getachew Agegnehu, Tadesse Gashaw, Tulu Degefu, Gizaw Desta, Kindu Mekonnen, Schulz, S., and Thorne, P. (2021). Short term fallow and partitioning effects of green manures on wheat systems in East African highlands. *Field Crops Research*, 269: 108175. https://doi.org/10.1016/j.fcr.2021.108175.

Vanlauwe, B. (2011). Integrated soil fertility management: operational definition and consequ ences for implementation and dissemination. Outlook Agric. 39(1): 17–24. https://doi.org/10.5367/000000010791169998.

Walling, E. and Vaneeckhaute, C. 2020. Greenhouse gas emissions from inorganic and organi c fertilizer production and use: A review of emission factors and their variability.

Journal of Environmental Management, 276, 111211. https://doi.org/10.1016/j.jenvma n.2020.111211.

Ward, P., Bell, A., Droppelmann, K. and Benton, T. (2018). Early adoption of conservation agriculture practices: Understanding partial compliance in programs with multiple ado ption decisions. *Land Use Policy*, 70: 27–37. https://doi.org/10.1016/j.landusepol.2017.10.001.

Warner, J., Yirga, C., Gameda, S., Rashid, S., and Alemu, D. (2016). Soil Acidity Problems in Ethiopia: Magnitude, Current Awareness and Practices, and Policy Actions. *Proceedin gs of the Research for Ethiopia's Agricultural Policy Presented for EIAR 50th Anniver sary, Addis Ababa, Ethiopia, 1*.

Warner, J., Mann, M., Chamberlin, J., Tizale, C.Y. (2023). Estimating acid soil effects on selected cereal crop productivities in Ethiopia: comparing economic cost effectiveness of lime and fertilizer applications. PLoS ONE 18 (1): e0280230. https:// doi.org/10.13 71/*journal.pone.0280230*.

Wegene Negese. (2019). Review on the extent of acid soil in Ethiopia, its impact and manage ment methods. *Journal of Biology, Agriculture and Healthcare*, 9(15): 24–36. https://doi.org/10.7176/JBAH.

Workineh Ejigu, Yihenew Selassie, and Eyasu Elias. (2022). Integrated use of compost and lime enhances soil properties and wheat (*Triticum aestivum* L.) yield in acidic soils of Northwestern Ethiopia. *International Journal of Recycling Organic Waste in Agriculture*, 12(2), 193–207. https://doi.org/10.1038/s41598-020-73291-x.

Workneh Bekere, Tesfu Kebede, and Jafer Dawud. (2013). Growth and nodulation response of soybean (*Glycine max* L.) to lime, Bradyrhizobium japonicum and nitrogen fertilizer in acid soil at Melko, South western Ethiopia. *International Journal of Soil Science*, 8(1): 25. https://doi.org/10.3923/ijss.2013.25.31.

Wubayehu Kidanemariam. (2022). response of barely *(Hordeum vulgare L.*) yield and yield components to lime and vermicomposting application on acidic soil of sanket lideta kebele Banja district northwestern Ethiopia. *Middle East Research Journal of Agriculture and Food Science*. https://doi.org/10.36348/merjafs.2024.v04i01.001.

Yang, R., Mitchell, C., and Howe, J. (2018). Relative neutralizing value as an indicator of actual liming ability of limestone and byproduct materials. *Communications in Soil Sci ence and Plant Analysis*, 49(10): 1144 1156.https://doi.org/10.1080/00103624.2018.14 4886.

Zelalem Yekoye. (2016). Farmers' Perception on Soil Erosion and Their Response to Conserv ation in Debre Elias District, Ethiopia. Vol. IV (9).

APPENDIXS

appendix 1: Conversion factor of man equivalent and adult equivalent

Age group	Man equivalent		Adult equivalent	
(years)	Male	Female	Male	Female
<10	0	0	0.6	0.6
10-13	0.2	0.2	0.9	0.8
14-16	0.5	0.4	1	0.75
17-64	1	0.8	1	0.75
>64	0.7	0.5	1	0.75

Source: (Storck *et al*., 1991)

Appendix 2: Conversion factors used to estimate tropical livestock unit equivalents

Animal category	TLU
Calf	0.25
Donkey (Young)	0.35
Weaned Calf	0.34
Heifer	0.75
Sheep and Goat (adult)	0.13
Caw and Ox	1.00
Sheep and Goat young	0.06
Horse	1.10
Chicken	0.013
Donkey (adult)	0.7

Source: (Storck *et al*., 1991)

Appendix 3: Test of multicollinearity and heteroscedasticity problems

Variables	VIF	1/VIF
Training	2.50	0.399860
Extension	2.39	0.417738
Age of hh head	1.98	0.505325
Household size	1.82	0.548003
TLU	1.44	0.692550
Plot no	1.42	0.703095
Farm size	1.29	0.775332
Credit	1.27	0.789546
Acid level	1.17	0.857616
Edc	1.14	0.876040
Distance	1.14	0.878676
Slop	1.12	0.894336
Land owner	1.05	0.951299
Mean VIF	1.52	

estat hettest

Breusch–Pagan/Cook–Weisberg test for heteroscedasticity

Variable: Fitted values of participation

H0: Constant variance

Chi^2 (1) = 56.52

Prob > Chi^2 = 0.00

Appendix 4: Household survey questionnaires

Dear respondents! This survey questionnaire is designed with the objective of collecting information on the lime adoption of wheat producer farmers. It therefore meant only for research purposes. For this purpose, your genuine responses to each of the survey questions are highly useful. There are no right or wrong answers. Your responses were confidentially used for this research purpose only. We highly appreciate for your willingness to participate as a respondent in this survey.

General instruction: Please circle the alternative preferred or write the right alternative on the space provided. For specific type questions please strictly follow the instruction given in each part of the question/questionnaire.

Date/month/year of interview___________________________

Name of kebeles_____________________________________

Village of the respondent_____________________________

Name of the respondent_______________________________

Name of data collector__________________________ signature________________

Name of supervisor____________________________ signature ________________

1. Demographic and Geographic Information

1.1. Sex of the household head:

0. Female 1. Male

1.2. Age of the household head: ________________________

1.3. Education level of the respondent:

1. Illiterate
2. Read and write only
3. Grade 1-6
4. Grade 7-8
5. Grade 9-12
6. Grade 12 and above

1.4. Household member's sex and age from the oldest to the youngest (Please exclude the HH head in the list).

	1	2	3	4	5	6	7	8	9	10	11	12
Sex												
Age												

2. Socio-Economic Characteristics

2.1. Annual income sources and sell in 2015 E.C.

Crop type	Unit	Quantity	Value (Birr)	Livestock type	Unit	Quantity	Value (Birr)
Cereals				Livestock			
▪ Teff	Qt			– Cow	No		
▪ Maize	Qt			– Ox			
▪ Wheat	Qt			– Heifer			
▪ Sorghum	Qt			– Calf			
▪ Barley	Qt			– Horses			
▪ Beans	Qt			– Donkey			
▪ Peas	Qt			– Mule			
▪ Soybean	Qt			– Sheep			
▪ Sesame	Qt			– Goat			
▪ Oil Niger				– Poultry			
				– Milk			
▪ Fruits				– Butter			
▪ Oranges				– Egg			
▪ Mangoes				– Honey(per annum)			
▪ Avocadoes							
▪ Bananas							
▪ Apple							
▪ Vegetables				– Other sources			
▪ Tomatoes				– Wage			
▪ Onions				– Aid			
▪ Potatoes							
▪ Pimento							
Total							

2.2. Labor participation of household head on farm:

0. Part time 1. Full time

2.3. Do you hire labor for farm operation?

0. No 1. Yes

2.4. Do you participate in some social/economical and local institutions (mahiber, and Idir etc.)?

0. No 1. Yes

2.5. If yes, what type of organization were you participated in?

1. Edir
2. Ikub
3. Mahiber
4. Other, specify________

2.6. Do your rare animal?

0. No
1. Yes

2.7. If yes indicate the type of animals do you rare in the households

Types of Livestock	Local bread	Exotic breed	Number owned
Ox			
Cow			
Bull			
Heifer			
Calf			
Sheep			
Goat			
Horses			
Donkey			
Mule			
Poultry			
Total			

3. Production, Land Use and Soil Acidity

3.1. Do you have farm land?

0. No
1. Yes

3.2. If yes, specify the total farm size __________ in Timad)

3.3. Land use in 2014/15 production year.

Plot number*	Crop/Tree/ Grass Type	Ownership Owned- 1 Rented in-2 Rented out-3 Shared in -4 Shared out - 5	Farm size (Timad)	Land use Cultivated-1 Grazing-2 Fallow-3 Homestead-4	Dominant soil color Black-1 Red-2 Brown-3	Dominant slop Non flat-0 Flat-1	Acidity level Low-0 High-1	Lime application No-0 Yes-1	Irrigation No-0 Yes-1
1									
2									
3									
4									
5									

6									
7									
8									
9									
10									
11									
12									

Note* If a plot is irrigated add -1 and not irrigated add -0 following the plot number (code).

3.4. Do you observe yield reduction in the previous ten years?

0. No
1. Yes

3.5. If yes, what is the cause of yield reduction?

1. Soil acidity
2. Drought
3. Mono-cropping
4. Shortage of rain
5. Wheat rust
6. Others specify______

3.6. Do you have soil acidity problem?

0. No
1. Yes

3.7. What indicators did you observe?

1. Change in soil physical characteri stics
2. Yield reduction
3. Weeds infestation.
4. Others specify______

3.8. What are the main causes of soil acidification by perception in your plot?

1. Inherent acidic parent material
2. Continuous cultivation and removal of crops residue
3. High rainfalls followed by leaching and erosion
4. If you have others specify___

3.9. Have you ever use lime technology in the last four years?

0. No
1. Yes

3.10. If you yes in Q 3.9 where, you get the lime?

1. Research center
2. Government supply
3. Supply of development partners (e.g. NGO)
4. Other please specify____

3.11. Did you get training on lime practice before?

0. No 1. Yes

3.12. If yes Q no. 14, who deliver you the training?

1. Government
2. DAS
3. NGO
4. Other specify________

3.13. What is your current state in utilizing lime inputs in your wheat production?

1. Started adoption recently
2. Continued adoption with increasing rate
3. Adopting with decreasing rate
4. You have a plan to adopt

3.14. Did you apply manure?

0. No 1. Yes

3.15. If you purchased it, how much does it cost/Qt? ___________________ Eth Birr/Qt

4. Information on Specific Wheat Production

4.1. Fill the following for wheat plots only

Plot No (Refer the code in Q3.3	Seed (Kg)		Herbicide		Pesticide		Lime applied in KG	Estimated Human Labor in Man-days	Estimated draft power in Oxen-days	Quantity produced in Kg
	Local	Improved	Unit	Qt	Unit	Qt				

5. **Information and Infrastructure**

5.1. Do you sell this year product in market?

0. No 1. Yes

5.2. What are the major problems in marketing your products?

1. Transportation problem
2. Lack of saleable surplus.
3. Inability to sell when prices are low
4. Low bargaining power
5. Low price of Agricultural produce
6. Other specify___________

5.3. On average how many minutes do you spend to arrive to the nearest input market from home? __ Min

5.4. On average how many minutes do you spend to arrive to the nearest crop market from home? __ Min

5.5. What is the most often means of transportation of the input from the market?

1. Human labor
2. Carts
3. Vehicles
4. Pack animals
5. Others specify _____

5.6. If you hire or rent the means of transportation, what is the cost to transport for 100kg of produce from farm gate to district (local) market in birr/quintals? __________.

5.7. How much does it cost (round trip cost in Birr) if you travel by a public car to district (local) market in birr/quintals? __________.

6. Institutional Support

6.1. Did you receive loan for this production year?

0. No
1. Yes

6.2. If yes, have you use credit for the purchasing of lime?

0. No
1. Yes

6.3. If yes for Q 6.2, the amount of loan. ________ ETH Birr

6.4. Do you have extension agent (DA) advice to use lime in wheat production?

0. No
1. Yes

6.5. If yes for Q 6.4, how can the development agent help you for the effective application of lime?

1. Practical assistance at farm
2. Training at FTC
3. Demonstration
4. Support to access lime input.
5. Other please specify _______

6.6. Yes, for Q 6.4, how do you evaluate the assistance given by the development agent service for the successful adoption of lime?

1. Excellent
2. Good
3. Poor

7. General Challenges and Recommendations About Lime Technology Application

7.1. Do you face any challenge in adoption process of lime input?

0. No 1. Yes

7.2.If yes for Q 7.1 what are the major challenges to the application of lime technology?

1. Transportation problem
2. Supply and distribution
3. High price
4. Shortage of labor
5. Long distance nearby market
6. High cost of transportation
7. No favorable road
8. Others specify________

7.3. What are your recommendations?

____
____
____

Thank you!