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Farmers' Perceptions of Agricultural Lime Technology, Contributions, and their Determinants in the Central Highlands of Ethiopia

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Abstract

Soil acidity poses a significant challenge to agricultural production in Ethiopia, with over forty-three percent of farmland affected, leading to low crop yields. Agricultural lime is widely recognized as an effective solution for addressing soil acidity. This study aims to evaluate the perception of smallholder farmers and factors influencing the adoption of agricultural lime technology in key intervention sites where research centers and other organizations have implemented interventions. A sample of 162 households from three study sites was chosen using a multi-stage random sampling method. Data was collected through structured interviews, focus group discussions, and key informant interviews. The Likert scale and ordered probit model were utilized to assess farmers' perceptions and determinants of agricultural lime technology adoption, respectively. The results revealed that the majority of farmers had a positive perception of the benefits of ag-lime technology. Farmers also demonstrated a good understanding of soil acidity issues on their farms, as well as the causes and potential mitigation strategies across all sites. However, significant challenges were identified, including limited availability of lime, accessibility, sustainability, and a lack of soil acidity testing services. The study also highlighted a strong and positive demand for lime technology, suggesting a need to strengthen the supply side by enhancing the capacity of private and public lime enterprises in terms of production and delivery. Therefore, it is recommended that stakeholders focus on variables that have shown a positive and significant impact on lime technology adoption to increase participation and effectively address soil acidity issues. By addressing these challenges, adoption of ag-lime technology could help improve crop productivity in areas prone to soil acidity.

Keywords: Acid soil; Adoption; Agricultural lime; Farmer; ordered probit; perception

Introduction

The prevalence of food insecurity and poverty continues to be a major issue in Ethiopia and other African countries. The economic well-being of the country is also dependent on the success of its agriculture. Agriculture continues to play a significant role in Ethiopian economic growth as it contributes approximately 32.4 % of GDP and employs 80 % of the national labor force (NBE, 2021). Over 80% of the population lives in rural areas and makes a living, directly or indirectly from agriculture. To ensure better agricultural productivity and food security in Ethiopia, a significant increase in crop yield is needed.

Agricultural transformation in Ethiopia requires the appropriate use of soil resources and smallholder farmers in Ethiopia are characterized by subsistence agriculture with low levels of productivity in part due to low soil fertility, low levels of input use including fertilizer and quality seed in general, and soil chemical degradation in the form of soil acidity in particular. Soil acidity is one of the key constraints that affect plant growth and ultimately limits crop production and productivity mainly in Nitisols of Ethiopian highlands (Zeleke et al., 2010). According to Elias (2016), 80% of Ethiopia's Nitisols are strongly acidic. Haile et al. (2017) estimated that 43% of Ethiopian cultivated land is affected by soil acidity. The Agricultural Transformation Agency (ATA) of Ethiopia reported that about 28.1% of these soils are dominated by strong acid soils (pH 4.1-5.5) (ATA, 2014). The problem of soil acidity is common where precipitation is high enough to leach appreciable amounts of exchangeable bases from the soil surface (Achalu et al., 2012). Soil acidity is expanding in scope and magnitude in Ethiopia, severely limiting crop production.

The cultivation of acid-tolerant crops, covering the surface with non-acidic soil, applying organic fertilizers, and liming are some of the technologies and practices suggested to restore soil acidity and improve the productivity of strongly acidic soils. Among these, liming and the application of organic fertilizers appear to be the most effective due to their longer-lasting agronomic effects (Chen et al., 2001; Desalegn et al., 2019; Warner et al., 2023). Ag-lime is a soil conditioner primarily composed of calcium carbonate and manufactured from crushed limestone, also known as dolomitic limestone. Ag-lime lowers soil acidity and raises alkalinity in acidic soil by increasing its pH. These soil conditions help plants absorb major plant nutrients (nitrogen, phosphorus, and potassium) and improve water penetration in acidic soils. Additionally, they supply calcium to plants. Applying agricultural lime, also known as "ag-lime," is a key method for reducing soil acidity and increasing crop yields. To address various points along the ag-lime value chain, Ethiopia has initiated an acid soil reclamation strategy (e.g., Warner et al., 2016; Amede et al., 2019). The project aims to provide farmers with adequate amounts of ag-lime in a timely, sustainable, and affordable manner.

Lime application is one of the most common methods recommended by the research system to reclaim acid soils. Research centers demonstrated lime technology in the large-scale farm through a clustering approach with full package recommendations in the west and southwest Shewa zone of the Oromia regional state on different cereal crops. In the study area, field performance evaluation and yield data results of reclaimed acid soil showed that application of lime with full package recommendation of food barley and bread wheat gave high grain yields.

Several demonstration studies were conducted to determine the effect of applying lime on acid soils to improve crop production and productivity. Tilahun *et al.*,

(2020) indicated that the application of lime integrated with improved varieties and management resulted in a yield advantage of 90.23%. Similarly, Kuma *et al*., (2018) also found that the grain yield of wheat with lime and NP fertilizer increased by 78.8% as compared to the control plot. Temesgen *et al*. (2016) showed that in the study of the effect of lime and phosphorus fertilizer on acid soils and barley performance in the central highlands of Ethiopia indicate that the combined application of 1.65 t ha $^{-1}$ lime and 30 kg P ha $^{-1}$ gave 133% more grain yield of barley as compared to the control (without lime and P). Getachew *et al*. (2017) in the study of the effect of lime and Phosphorus fertilizer on acid soil properties and barley grain yield at Bedi showed that the highest yield was obtained from 2.2 t ha^{-1} lime application combined with 30 kg/ha phosphorus fertilizer. The application of 1.65 t ha^{-1} lime and 20 kg/ha phosphorus increased the grain yield by 274% in the first years compared with the control. But in the subsequent years grain yield obtained steadily decreased to 224, 174.9, 164, and 99.5% respectively.

Despite these efforts, as the research intervention withdraw from area, we noticed that there was no significant increase in the adoption of lime technology in the community, as well as in neighboring kebeles or other districts. Therefore, the main research gap in this study is to understand why the technology is not spreading as anticipated to other areas affected by soil acidity. Additionally, this study assessed farmers' perceptions of the barriers and challenges associated with expanding agricultural lime technology to new areas affected by soil acidity. Ultimately, the finding of this study provides policy recommendations for future research and interventions.

Theoretical Background

Definition of Farmer Perceptions

Within the context of agricultural technology adoption, this research defines farmer perceptions as the farmer's subjective preferences, which are fundamental characteristics that may impact decision-making processes (Adesina and Baidu-Forson, 1995). Farmer perceptions are affected by a variety of prior behaviors, experiences, and observations, as well as future aspirations. These are also influenced by a variety of external factors, including individual and household characteristics, institutions, socioeconomic conditions, and environmental conditions (Jha *et al*., 2019). Farmers' perceptions may shift over time when new information becomes available and earlier perceptions adapt (Meijer *et al.*, 2015). Farmer impressions may or may not correspond to actual reality (Jha *et al*., 2020; Zemarku *et al.*, 2022). As a result, to avoid biased results, the study takes into account all farmer impressions, whether they reflect reality or not.

Agricultural lime production in Ethiopia

Agricultural lime is produced by both private- and public-possessed lime processing factories. Still, both the public and private agricultural lime processing manufactories are operating below their capacity. Government-possessed lime crushers (Guder, Dejen, and Kella lime manufactories) were supposed to operate at full capacity. Still, due to limited demand and other internal functional challenges, the three manufacturers are operating at sub-optimal capacity. Dashen cement plant has a large agricultural lime processing capacity but in 2021, it produced only 2 percent of its maximum capacity. The plant produced only the volume of lime contracted to it by the Amhara Regional Government for the 2020/2021 product season (Oumer et al, 2023).

Similarly, due to insufficient demand for ag-lime, the Muger cement factory, with the greatest processing capacity, produces less than 1% of its maximum capacity (Oumer et al, 2023). We argue that producing a large volume of agricultural lime should not be a problem in Ethiopia, given the potential in ag-lime processing at cement factories that could easily adjust to produce lime for agriculture and manufacturing establishments dedicated to lime crushing. Public lime plant directors have stated that a lack of demand and low production levels are primarily caused by the government-owned lime crushers' lack of financial autonomy and critical comments. The Ethiopian government established lime plants in Guder, Dejen, and Kella to supply agricultural lime for soil acid treatment. The lime plant directors claim that these factories receive their operating budget from separate District Finance services they are affiliated with, and that these services also receive revenue from lime sales. Government services oversee all procurement matters, including the replacement of spare parts for equipment maintenance. Managers of the Guder and Dejen factories have highlighted inefficiencies that arise, particularly when maintenance issues occur during peak processing times for lime (Oumer et al, 2023)

Agricultural lime technology popularization

In Ethiopia, agricultural lime technologies are being popularized through a variety of extension techniques. This is expected to create demand for ag-lime by farmers. For instance, the MoA Soil Resources Development Desk trains regional states once a year to become trainers (ToT) in the management of acid soils. Additionally, the Directorate broadcasts customized programs on acid soil management and agricultural lime technologies through public media. Agricultural extension professionals, large- and small-scale demonstrations, field days, public media, leaflets, cluster farming, and training on soil acidity and its management measures, including liming, were the main popularization techniques used in all regions.

Numerous organizations, including research institutions, Bureaus of Agriculture (BoAs), and non-governmental organizations (NGOs), such as the German Technical Cooperation (GIZ), are actively involved in promoting agricultural technology. The Ethiopian Institute of Agricultural Research (EIAR) also plays a significant role in promoting ag-lime through training, field days, demonstrations on both local and large scales, and cluster farming. Ag-lime technologies are disseminated to farmers through various electronic media channels. NGOs like GIZ support the showcasing of lime technologies to farmers and raise awareness through posters, brochures, field days, farmers' field schools, and the media. Various news stories, documentaries, and radio and television shows have highlighted the use of ag-lime in collaboration with the BoA.

In spite of this effort, experts have identified the lack of demand as the primary obstacle to the poor uptake of agricultural lime in the country. Additionally, lime is a relatively new and uncommon production input for smallholder farmers, making it challenging for them to adopt it. Farmers have historically faced difficulties in using even well-known production inputs like fertilizer and high-quality seedlings. The large volume of ag-lime required per unit of area, unlike fertilizer and seed, presents challenges in transportation and purchase. Experts suggest that persuading farmers to invest in agricultural lime is difficult due to these reasons (Oumer et al, 2023)

Methodology

The study area

A multi-stage stratified random sampling technique was employed to select a representative sample for this study. In the first stage, districts from the west and southwest of the Oromia region were purposively selected based on lime intervention practices in the area. In the second stage, six kebeles were purposively chosen from four districts based on their potential for lime intervention. These kebeles include Damotu from Ejere district, Dufa from Wolmera district, Wechecha and Markos from Menagesha district and Adami Gotu and Maru Babali from Woliso district.

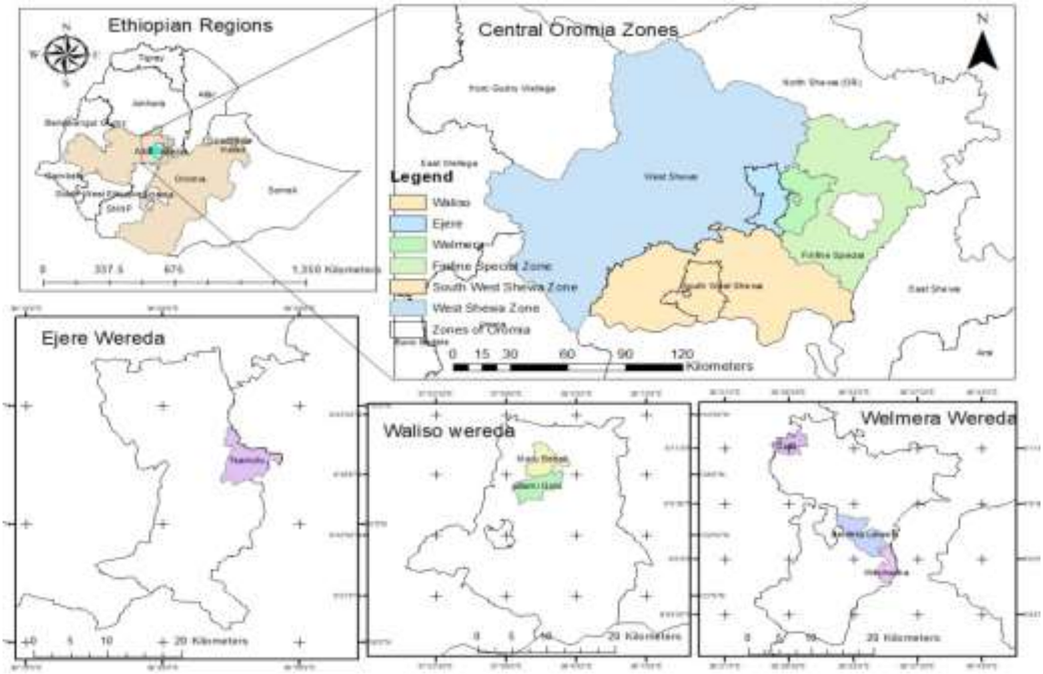

Fig 1. Map of the study area
Source: (Ethio-geospatial data)

Sampling method and size

A multi-stage stratified random sampling technique was employed to select a representative sample for this study. In the first stage, districts from the west and southwest of the Oromia region were purposively selected based on lime intervention practices in the area. In the second stage, six kebeles were purposively chosen from four districts based on their potential for lime intervention. These kebeles included Damotu, Dufa, Wechecha, Markos, Adami Gotu, and Maru Babali.

Thirdly, within the selected Kebeles, 162 farm household heads were randomly selected using probability proportionate to size. The total sample size (n=162) was determined using Yamane's formula (1967). The formula was employed to determine the required sample size at a 95% confidence level, a degree of variability of 0.5, and a level of precision of 5% (0.05).

$$n = \frac{N}{1 + N(e)2} \quad [1]$$

Where N = total population of the sample kebele, n = sample size to be computed, and e = acceptable error (level of precision), which is assigned a value of 5 percent (0.05).

Methods of Data Collection

In this study, both qualitative and quantitative data from primary and secondary sources were utilized. Secondary data was collected by reviewing published documents, which was used to evaluate existing works and compare the study with previous research. Primary data was collected through two survey procedures: formal and informal surveys.

In the informal survey, key informant interviews and focus group discussions were conducted with respondents and development agents. These interviews and discussions were guided by a checklist. A total of 6 focus group discussions and 15 key informant interviews were conducted. In the formal survey, data was collected using a semi-structured household survey questionnaire through face-to-face interviews with household heads.

Data Analysis Techniques

Descriptive and inferential statistics and econometric models were used to analyze the data collected. STATA statistical software (STATA 15 version) was used to analyze the data. Qualitative data obtained from focus group discussions and key informant interviews were used to support the quantitative findings.

An ordered probit regression model was used for this study to analyze the determinants of farmers' perception of lime technology usage and participation. This model helped to regress the relationship between the dependent variable and a set of explanatory variables.

In an opinion survey, the response options selected are often presented as a discrete set rather than a continuous one. The ordered probit model is particularly useful when the dependent variable can take more than two values and these values have a natural ordering, as is common in survey responses. When dealing with multiple ranked discrete dependent variables, the Ordered Probit model is a straightforward extension of the binary probit model that can be applied. There are two types of discrete choice variables: ordered and unordered variables. Previous research has mainly focused on examining the statistical relationships between dependent and explanatory variables using multiple regression models, as well as binary probit or logit models. Ordinary least squares regression would not be appropriate for this investigation due to the discrete nature of the dependent variable. For dichotomous dependent variables, the Probit or Logit model specifications are used, which also yield discrete outcomes.

Given this, the data analysis is better suited to a multinomial model for the discrete choice of ordered data. However, compared to binary logit and probit models, the ordered probit model is statistically more efficient since it can utilize all response choices. Therefore, this investigation utilized the ordered probit model with Maximum Likelihood (ML) analysis (Borooah, 2002). It is possible to create threshold models with a latent dependent variable for ordinal dependent variables.

$$y_i^* = \beta_i' x_i + \varepsilon_i \quad [2]$$

Where, Y_i' is an unobserved variable.it is assumed that Y is normally distributed with a zero mean.β' is a vector of respondent characteristics.

The ordered probit model was utilized to analyze the factors influencing farmers' perceptions of the lime technology's impact on improving land affected by participation. The dependent variables were categorized as 1, 2, and 3, representing "agree," "disagree," and "strongly disagree," respectively, on farmers' perceptions of the lime technology's effect and participation. The model, based on the latent regression function, was specified as:

$$Y = \begin{cases} 1, & if \quad Y_i^* < \mu_1 \\ 2, & if \quad \mu_1 < Y_I^* < \mu_2 \\ 3, & if \quad Y_i^* > \mu_2 \end{cases} \quad [3]$$

Where μ1 and μ2 are the classifying threshold values.
Equation (1) and (2) can be used to specify the empirical model given in equation (3).

$$\begin{aligned} y(PLT)^* = \beta_0 + \beta_1 AGE + \beta_2 Gender + \beta_3\, HHEDU + \beta_4\, LABOR + \beta_5\, HHSIZE \\ + \beta_6\, ACCTOLIMCER + \beta_7\, ACCTOLIMINP \\ + \beta_8\, ACCTOGENINPU + \beta_9\, ACCTOEXT + \beta_{10}\, FAEXPR \\ + \beta_{11}\, DISTOMKT + \beta_{12}\, DISTOLIMKT + \beta_{13}\, DISTAGRI \\ + \varepsilon \quad [4] \end{aligned}$$

Where the variables used in equation (3) are defined in Table 1

Data and Analytical Model

The study collected data on variables such as socio-economic factors, farm structure, and lime input usage as independent variables, in line with the study's objective. The dependent variable (PLT) was the perception of farmers' lime technology usage and their awareness of its effects on improving land affected by acidity.

Independent variables included Socioeconomic variables: (AGE) Household head age, (Gender) Gender of Household head, (HHEDU) Household head education status, (LABOR) Family labor, (HHSIZE) Household family size, (FAEXPR) Farmers' farming experience. Institutional variables included: (ACCTOLIMCER) Farmers' access to lime input credit, (ACCTOLIMINP) Farmers' access to lime inputs, (ACCTOGENINPU) Farmers' access to general inputs, (ACCTOEXT) Farmers' access to extension service, (DISTOMKT) Distance to nearest market (walking minutes), (DISTOLIMKT) Distance to nearest market (walking minutes), (DISTAGRI) Distance to agricultural office (walking minutes).

Table 1. Variables used in ordered probit model.

Covariate name	Description of variables	Measurement units
PLT	Farmers perception of lime technology effect in ameliorating acid soil	y_i^*1 to 3 levels ordinal
AGE	Household head age	Continues
Gender	Gender of household head	Dummy
HHEDU	Household head education status	continues
LABOR	Family labour	continues
HHSIZE	Household family size	continues
ACCTOLIMCER	Farmers' access to lime input credit	Dummy
ACCTOLIMINP	Farmers' access to lime inputs	Dummy
ACCTOGENINPU	Farmers' access to general inputs	Dummy
ACCTOEXT	Farmers' access to extension service	Dummy
FAEXPR	Farmers farming experience	Continues
DISTOMKT	Distance to nearest market (walking minutes)	Continues
DISTOLIMKT	Distance to nearest market (walking minutes)	Continues
DISTAGRI	Distance to the agricultural office(walking minutes)	Continues

Results and Discussion

Descriptive Results

The variables in this section are represented by descriptive statistics including frequency, percentage, mean, and standard deviation. Additionally, chi-square and t-tests were utilized to assess the relationship between categorical and continuous variables in relation to agricultural lime technology perception by smallholder farmers.

Demographic and socioeconomic characteristics of the respondents

The summary of descriptive statistics for continuous and categorical variables used in this study is presented in Tables 2 and 3, respectively. The average age of a farmer household head was 45.6 years. This finding suggests that older household heads in Ethiopia's central highlands have a better perception of agricultural lime technology compared to younger household heads. One key continuous variable describing farmer households is family size, with an average of 5.2 members. In terms of family labor in the study area, the average is 4.2. The average distance to the nearest market is 114 walking minutes, while the average distance to the nearest lime market is 15.9 and the average distance to the nearest agricultural office is 30.42 walking minutes (see Table 2).

Table 3. Shows that the level of education among the sampled household heads varied. Of the respondents, 28.40% were literate, while the majority, 71.60%, was illiterate.

Table 2. Socioeconomic characteristics of respondents for continuous variables.

Covariate	(N=162)		
	Mean	SD	t-test
Age of Household head (years)	45.6	14.8	-0.0221 NS
Family size (number)	5.2	1.97	-0.3015 NS
Family labour(number)	4.2	1.35	0.023**
Distance to nearest market(walking minutes)	114.6	70.12	-3.5454***
Distance to nearest lime market(walking minutes)	15.9	14.5	0.1542 NS
Distance to agricultural office (walking minutes)	30.42	27.15	-0.1150 NS

Abbreviation: NS, non-significant, *Significant at 10%, **significant at 5%,***significant at 1%.
Source: Own survey data (2023).

In terms of gender composition, 82.10% of the respondents in the study area were male-headed households, while 17.90% were female-headed households. Regarding access to agricultural inputs and services, 79.01% of households in the study area had access to agricultural extension services, while 20.99% did not. When it came to credit access for lime inputs, 90.74% had access, while 9.26% did not. Only 43.21% had access to credit for the purchase of general inputs for their farming. Lastly, in terms of access to agricultural lime inputs, 82.72% had access, while 17.28% did not.

Table 3. Distribution of households based on categorical variables

Covariates	(N=162)			
	Categories	Freq.	Percent	Chi^2 –value probability
Access to extension service	Yes	128	79.01	1.5NS
	No	34	20.99	
Access to credit for lime input	Yes	147	90.74	3.45*
	No	15	9.26	
Access to general inputs	Yes	70	43.21	0.63NS
	No	92	56.79	
Gender of Household head	Male	133	82.10	0.28NS
	Female	29	17.90	
Household head education status	Literate	46	28.40	10.46NS
	Illiterate	116	71.60	
Access to lime inputs	Yes	134	82.72	0.61**
	No	28	17.28	

Abbreviation: NS, non-significant, *Significant at 10%, **significant at 5%, ***significant at 1%.
Source: Own survey data (2023).

Farmers' Perception of Soil Acidity

According to farmers' practices, local soil management techniques, such as fallowing cropland to increase land productivity, were used to address issues with soil acidity and fertility. However, due to land scarcity and the challenge of sustainably solving the issue of soil acidity over time, fallowing cropland has limited possibilities (Warner *et al.*, 2023). Our qualitative findings show that farmers are aware of the issues with soil acidity and the methods for mitigating them. Researchers and Development Agents (DA) educate farmers about soil acidity. Additionally, some farmers received tailored training on soil acidity, which they then shared with other farmers. Low crop growth and productivity, even with the application of inorganic fertilizer, are further signs of acidity in the soil that farmers might observe on their properties.

Farmers often report experiencing entire crop failures due to acidic soil. Soil acidity is primarily attributed to over-ploughing, continuous cropping without leaving crop residues, and soil erosion, according to farmers. Farmers utilize a variety of techniques to mitigate soil acidity, as revealed in the focus group discussions. These techniques include using ag-lime, rotating crops with legumes, and applying compost and manure. Due to extreme soil acidity, farmers plant eucalyptus trees on unresponsive farmlands and grow wild oats known locally as "sinar." It is believed that these crops can thrive in acidic soil. Farmers are also aware that even the growth of eucalyptus trees is affected by the severity of soil acidity.

Agricultural lime technology perception, utilization trend, source, and challenges

In the study area, the application of lime technology and its area coverage trends show an increasing but decreasing rate over the years (Fig 2). This is attributed to the inconsistent supply of lime inputs in the study area, as previous interventions were mainly carried out by research centres and other organizations. Based on the findings from focus group discussions and key informant interviews, we observed that once these organizations ceased their interventions, the study area reverted to its pre-intervention state. Therefore, future interventions should focus on ensuring a timely and sufficient supply of lime technology across the ag-lime value chain to strengthen agricultural lime supply in the study area.

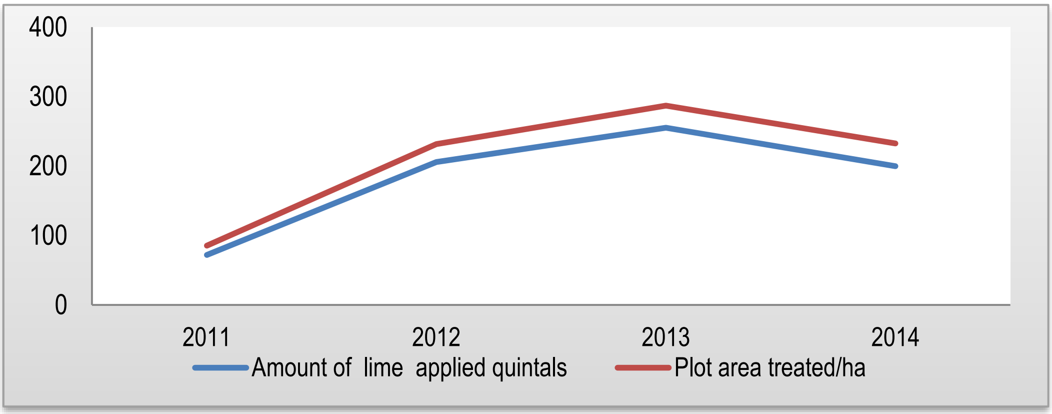

Figure 2: Farmers' lime technology application and area coverage over years in the study area
Source: Own survey data (2023)

Agricultural lime is produced by both privately and publicly owned lime processing plants. However, both public and private ag-lime processing factories are operating below their potential capacity. Government-owned lime crushers (Guder, Dejen, and Kella lime factories) were supposed to operate at full capacity. However, due to limited demand and other internal operational challenges, the three factories are operating at suboptimal capacity. Moreover, we noted that respondents in the study area received lime technology information that could improve their acidic soil from various sources. According to the study findings, 70.23% of respondents obtained lime technology through research intervention, while 25% received it from government extension services/BOA respectively (see fig 3).

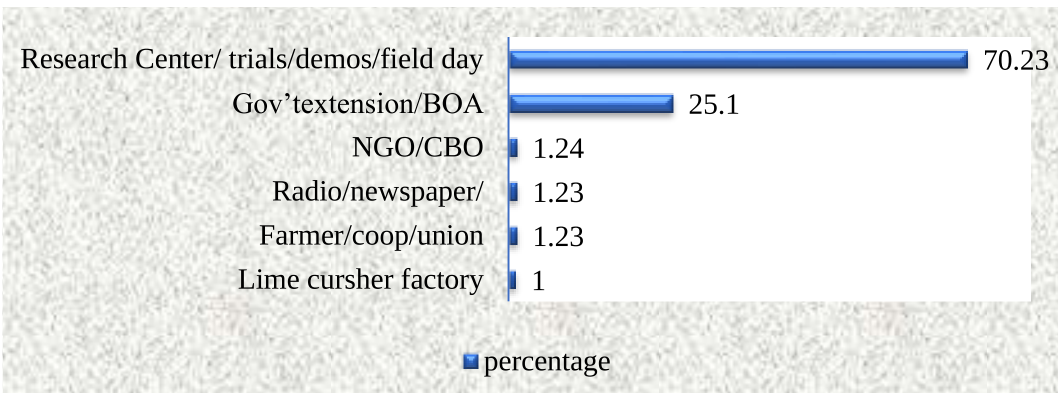

Figure 3: First source of information about Lime technology
Source: Own Survey data (2023)

The Ethiopian Institute of Agricultural Research (EIAR) promotes agricultural lime through small-scale and large-scale demonstrations, field days, training, and cluster farming. Nearly all respondents received lime technology for free for their acid-affected plot, while only 1.23 percent of respondents paid a portion of the cost (Figure 4). In this section, farmers were asked about their willingness to pay for lime technology. Nearly 95 % of respondents said they were unwilling to pay because the cost of inorganic fertilizer already posed a burden, and charging for lime technology would result in a double burden.

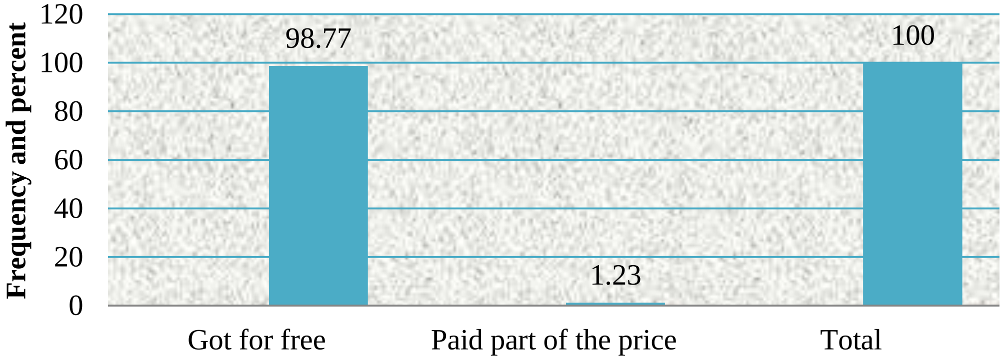

Figure 4: Respondent's first lime input use
Source: Own Survey data (2023)

We observed that efforts to popularize agricultural lime technology are being carried out by various stakeholders, including research institutes, Bureaus of Agriculture (BoAs), and NGOs, particularly the German Technical Cooperation (GIZ). In this study, the intervention of research centers in large-scale demonstration activities resulted in a significant supply of lime technology, accounting for 76.5 percent according to the survey results. Other stakeholders, as depicted in Figure 5, also made contributions, with 9.3 percent coming from farmers to farmers' exchange, 6.8 percent from government subsidy programs, 6.2 percent from NGOs providing free assistance, and 1.2 percent from farmers' group/cooperatives, among others.

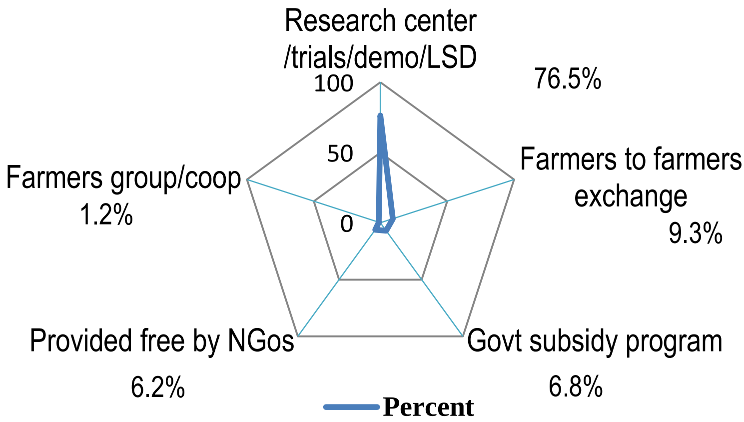

Figure 5: Respondent's first lime input use source
Source: Own survey data (2023)

Among the farmers interviewed, the majority expressed interest in continuing to utilize lime technology in the future due to its potential to reclaim their acid soil. However, only 3.7% expressed disinterest, citing issues such as changes in soil texture, the bulky nature of lime, difficulty transporting it to farm plots, the labor-intensive nature of lime application, concerns about permanent dependency on lime for their acid-affected soil, and limited supply to remote kebeles (figure 6).

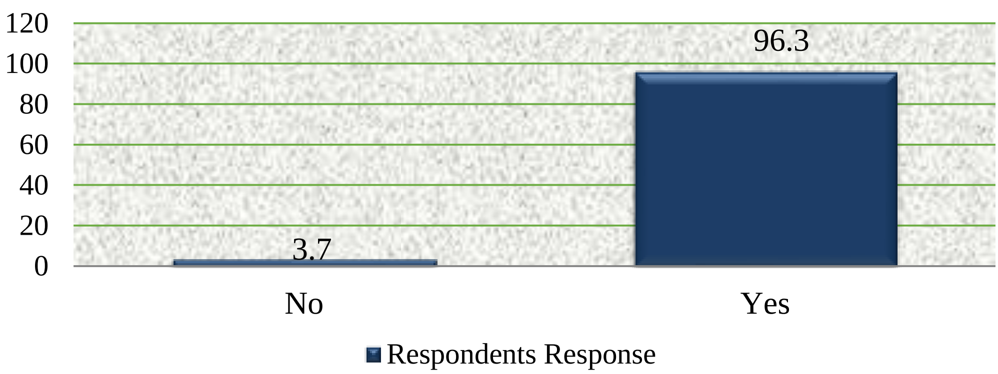

Figure 6: Respondent's willingness to continue lime use in the future
Source: Own survey data (2023)

Currently, study areas are not utilizing lime inputs for various reasons. The survey results indicate that 77.8% of respondents cited lime availability issues as the main reason for not using lime technology. 12.96% did not provide a reason, 3.7% mentioned the high labor required to spread lime on farms, 2.47% stated difficulties in transporting lime to the farm, 1.85% found the benefits of lime unclear, and 0.62% attributed low grain prices as the reason (Figure 7). The qualitative findings, particularly from key informant farmers, highlighted barriers to ag-lime adoption in the study areas. These barriers include the bulky nature of lime, challenges in transportation to farm plots (due to lack of simple machines), labor-intensive application of lime, late supply of lime, and limited supply to remote areas. Farmers recommended a timely supply of lime, access to spreading machines, credit, and subsidies to promote the widespread use of agricultural lime. These support services have also been suggested in previous studies (Warner *et al.*, 2016; *Tamene et al.*, 2017; Gurmessa, 2021; AGRA, 2022).

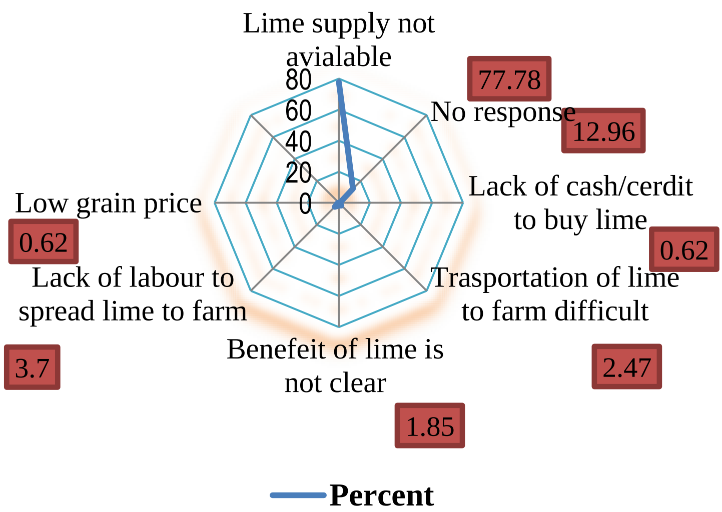

Figure 7: Principal reasons for not using lime in the current season
Source: Own survey data (2023)

The constraints related to acid soil issues have been discussed with respondent farmers in the study area. This discussion was based on the survey results, specifically the respondents' responses regarding constraints in accessing key inputs and services related to lime technology. Apart from the availability of lime, availability of government extension services was cited as major constraints by respondents in the study area (see Table 4).

Table 4. Respondent's response on constraints in accessing key input, services related to lime technology

Questions	(N=162)		
	Categories	Freq.	Percent
soil acidity testing service is a constraint in your crop production	Yes	162	100
	No	0	0.0
Is the availability of lime a constraint in your crop production	Yes	162	100
	No	0	0.0
Is the availability of lime transportation options a constraint	Yes	161	99.38
	No	1	0.62
Is the availability of small-scale machinery for spreading lime improved a constraint?	Yes	162	100
	No	0	0.0
Is availability of government extension service on lime a constraint	Yes	15	9.26
	No	147	90.74

Source: Own survey data (2023)

To increase farmers' awareness of lime technology, various extension and advisory services tailored to farmers are necessary. Based on the findings, approximately 95% of the respondents expressed interest in receiving information, advice, or training on soil management practices, including lime technology. Providing such training and advisory services is recommended as it would help enhance smallholder farmers' understanding and perception of lime technology application, as well as its significance in reclaiming acidic soil farmlands (see Table 5).

Table 5. Respondents' information/advice/training need in acid soil management practice

Questions	(N=162)		
	Categories	Freq.	Percent
Do you need extension training/information /advice about soil acidity tests?	Yes	154	95.06
	No	8	4.94
Do you need extension training/information /advice about treating soil acidity with lime?	Yes	160	98.77
	No	2	1.23
Do you need extension training/information /advice about new varieties of crops coping with soil acidity problems?	Yes	157	96.91
	No	5	3.09
Do you need extension training/information /advice about soil and water management?	Yes	160	98.77
	No	2	1.23
Do you need extension training/information /advice about crop rotation and intercropping?	Yes	156	96.09
	No	5	3.09
Do you need extension training/information /advice about Minimum tillage?	Yes	38	23.46
	No	124	76.54
Do you need extension training/information /advice about leaving crop residue in the field?	Yes	141	87.04
	No	21	12.96

Source: Own survey data (2023)

In a similar vein, the study confirmed that respondents in the study area had received training, information, and advice regarding acid soil management practices. The findings revealed that over 75% of respondents had received information or advice on all soil management practices, while the remaining percentage had not received any training or farmer advisory services on acid soil management practices, specifically agricultural lime technology utilization. To enhance awareness and knowledge of acid soil management among this segment of the population, future interventions should focus on providing training and extension services (see Table 5).

Table 6. Training/information/advice received in acid soil management practice

Questions	(N=162)		
	Categories	Freq.	Percent
Did you receive extension training/information /advice about the soil acidity test?	Yes	128	79.01
	No	34	20.99
Did you receive extension training/information /advice about treating soil acidity with lime?	Yes	124	76.54
	No	38	23.45
Did you receive extension training/information /advice about new varieties of crops coping with soil acidity problems?	Yes	120	74.07
	No	42	25.92
Did you receive extension training/information /advice about soil and water management?	Yes	129	79.63
	No	33	20.37
Did you receive extension training/information /advice about crop rotation and intercropping?	Yes	128	79.1
	No	34	20.99
Did you receive extension training/information /advice about Minimum tillage?	Yes	102	62.96
	No	60	37.04

Source: Own survey data (2023)

Respondent's perception of the effect of lime technology practices

This study presents the farmer's perspective on the effects of lime technology practices and lime-related issues. Twelve statements regarding various lime technology effects and related practices were evaluated. A 3-point Likert-type scale was used to assess respondents' perceptions of various lime technology practices. Respondents were asked to choose one of the available options for each statement/item. The responses from the sample households were then analysed using frequency, percentage, and mean values, as the Likert scale ranged from 1 to 3 (1 for agree, 2 for disagree, and 3 for strongly disagree). Table 5 displays how each respondent in the study area viewed the effects of lime technology practices and lime-related issues, along with a brief discussion of each statement (see Table 7).

Table 7. Perception of the respondents on the effect of lime technology practices and lime-related issues

	Respondents' distribution based on their response				
Questions	**A(3)**	**DA (2)**	**SD(1)**	**Mean**	**STD**
Improve the Quality of the soil	158(97.53)	4(2.47)	0 (0)	2.25	1.76
Reduce the Acidity level of the soil	154(95.06)	8(4.94)	0 (0)	2.15	1.71
Availability of lime improved	49(30.25)	105(64.81)	8 (4.94)	1.93	1.41
Availability of credit for lime purchase improved	51(31.48)	84(51.85)	27(16.67)	2.81	2.30
The availability of farming practice information improved	11(6.79)	128(79.01)	23 (14.2)	2.64	2.14
Availability of govt. extension service on lime improved	133(82.10)	28(17.28)	1 (0.62)	2.56	2.06
Availability of other advisory services on lime improved	105(64.81)	55(33.95)	2(1.23)	2.88	2.35
Acid soil management technologies improved in availability	92(56.79)	68(41.98)	2 (1.23)	1.90	1.42
Availability of lime transportation options	143(88.27)	19(11.73)	0 (0)	1.62	1.15
The availability of small-scale machinery for spreading lime improved	18(11.11)	110(67.90)	34(20.99)	2.90	2.37
Availability of farm labor improved	6(3.70)	89(54.94)	67 (41.36)	2.25	1.76
Increase yield of major crops	147(90.74)	14(8.64)	1 (0.62)	2.15	1.71

Source: Own survey data (2023)
The numbers with ( ) percentages and the numbers without ( ) frequency A (Agree), N (Disagree), and SD (Strongly disagree). Source: Own survey data, 2023

The respondents' perceptions regarding the impact of lime technology and associated issues were categorized into Agree, Disagree, and Strongly Disagree. The majority of respondents agreed with the statements provided, while some disagreed, particularly regarding the availability of lime, farming practice information, small-scale machinery for spreading lime, and farm labor issues. These perceptions were reflected in the mean scores. In the Strongly Disagree category, some respondents expressed a negative view, believing that things were deteriorating compared to the previous scenario. They felt that the availability of lime-related practices had not improved, but rather had worsened, as indicated by all the statements mentioned above.

The statements "Improve the Quality of the soil" (Mean = 2.25) and "Reduce the Acidity level of the soil" (Mean = 2.15) received mean values closer to 1, indicating strong agreement that lime practices effectively improve soil quality and reduce acidity. Similarly, there is notable agreement that lime technology contributes to an "Increase in yield of major crops" (Mean = 2.15), reinforcing the perceived benefits of lime use in agriculture. Generally, the mean values reveal that while there is strong agreement on the benefits of lime in improving soil quality and crop yield, there is less consensus on the improvement of associated services and resources such as availability of credit, advisory services, machinery, and labor for lime technology practices.

Econometric model result

This study conducted all necessary model diagnosis tests, which included a model specification test for overall model fit (goodness of fit), a multicollinearity problem test, and a test for a model specification error. The model test was carried out before running the ordered probit regression, while model specification error tests (linktest) were conducted after the regression.

Explanatory variables were checked for multicollinearity, endogeneity, and heteroscedasticity issues. Following Gujarati *et al.* (2004), the problem of multicollinearity for continuous explanatory variables was assessed using the variance inflation factor (VIF) and tolerance level (TOL) technique, where each continuous explanatory variable was regressed on all other continuous explanatory variables. A VIF exceeding 10 and R^2 exceeding 0.90 indicates high collinearity. In this study, the VIF values for explanatory variables were less than ten, indicating no serious multicollinearity issue. Contingency coefficients were computed to check the association among dummy explanatory variables, with all values found to be less than 0.7.

There were no explanatory variables expected to be endogenous in the model, so an endogeneity test was unnecessary. To address the issue of heteroscedasticity, robust standard error was estimated. The model estimation involved an ordered probit regression to identify factors influencing farmers' perception of lime technology use and participation. The estimated coefficients of the ordered probit regression model are presented in Table 8.

Ordered probit model analysis results

The results of the ordered probit regression method were used to determine the relationship between farmers' perception of lime technology's effect on ameliorating acid soil and explanatory variables. The results of the probit analysis of the 162 observations are presented in Table 6. The quality of fit of the model shows an acceptable pseudo-R^2 of 0.6020 and significance at the 1% level (P=0.000), indicating that the model fits the data well. This suggests that 60% of the variability of perception can be explained by sets of variables selected from the ordered probit regression model.

The ordered probit model focused on variables that influence farmers' perception of lime technology used to reclaim acidic agricultural land. A total of thirteen predictor variables were included in the econometric model. According to the regression results, eight explanatory variables (Gender, education, access to lime, access to lime credit, access to extension service, access to general inputs, distance to market, and distance to agricultural office) were statistically significant.

Conversely, it is negatively influenced by age, labor, family size, farming experience, and distance to the lime market.

This means that the eight predictors had a greater impact on the household perception of lime technology in the study area than others. The change in the size of these predictors caused an improvement or worsening in the household's perception at the magnitudes indicated by their respective coefficients, indicating how much these factors are responsible for the change in the level of perception (Table 8). Therefore, addressing these constraints would improve farmers' perception and adoption of lime technologies. This, in turn, would contribute to improving rural smallholder farmers' productivity and livelihoods in Ethiopia, particularly in Oromia.

Table 8. Parameter estimates of the ordered probit regression model for factors that influence farmers' perception of lime technology use and participation

Variables	**Coef**	**Std .error**	**z**	**P>|z|**
AGE	-.0025919	.002644	-0.98	0.329
Gender	-.1663426**	.0671834	-2.48	0.014
HHEDU	.0200632***	.0066632	3.01	0.003
LABOR	-.0254918	.0240439	-1.06	0.291
HHSIZE	.0035132	.0030313	1.16	0.248
ACCTOLIMCER	.0452902*	.0248733	1.82	0.071
ACCTOLIMINP	.249669***	.0500076	4.99	0.000
ACCTOGENINPU	.1112049**	.0510035	2.18	0.031
ACCTOEXT	.1035591**	.0515282	2.01	0.046
FAEXPR	.0009491	.0030313	0.31	0.758
DISTOMKT	-.002055***	.0004018	-5.11	0.000
DISTOLIMKT	.0015487	.00019139	0.81	0.420
DISTAGRI	-.0025503**	.0009936	-2.57	0.011
/cut1	2.176022	1.6640015		
/cut2	4.974153	1.7542118		
Number of obs = 162				
LR chi2(12) = 44.96				
Prob >chi2 = 0.0000				
Pseudo R2 = 0.6020				
Log likelihood = -81.995427				

***, ** and * denotes significance level at 1%, 5% and 10% respectively.
Source: Own survey data (2023).

Gender differences are found to be one of the factors influencing the perception and adoption of new technologies. Due to various socio-cultural values and norms, males have more freedom of mobility and participation in numerous extension programs, resulting in greater access to information. The model output revealed that the gender of the household head had a positive and significant effect on farmers' perception of agricultural lime technology at a 5% probability level (P=0.014). The negative sign of the gender variable indicates that the majority of surveyed farmers are male and are primarily engaged in agriculture. While these male farmers are more aware of lime technology compared to their counterparts, their perceptions about agricultural lime inputs remain limited due to their low levels of involvement in extension programs. Previous studies by Mesfin (2005) and Taha (2007) support this finding, showing that male farmers are more likely to expose more information and as a result adopt new agricultural practices.

Education level is defined as the number of schooling years completed by the respondents, and it is a continuous variable. Education enables farmers to access new information and ideas. The analysis results demonstrate that the respondent's education level (HHEDU) had a positive and significant relationship with farmers' perception of lime technology at a 1% probability level (P=0.003). This study shows that the educational level of household heads positively influences farmers' perception of agricultural lime technology, playing a crucial role in improving awareness and adoption. Therefore, the higher the education level of the household head, the more likely farmers are to be aware of and adopt agricultural lime.

Another important point is the access to lime input credit (ACCTOLIMCER). The ordered probit model shows significance at 1% (P=0.000) and a positive impact of this variable on the farmers' agricultural lime perception. The study area indicates that households with more access to lime input credit through development agents are more likely to improve farmers' perception of lime technology compared to households with little or no access to credit. Moreover, for every unit increase in access to inputs, the probability of perception and adoption of lime technology increases by 45%.

Another important predictor variable is farmers' access to ag-lime input (ACCTOLIMINP) and access to general agricultural inputs (ACCTOGENINPU). Access to general agricultural inputs is believed to influence farmers' perception of agricultural lime technology. The ordered probit model output revealed that both access to lime input and general agricultural inputs positively impact the probability of farmers' perception and adoption of agricultural lime technology at a 1% (P=0.000) and 5% (P=0.030) probability level, respectively. Additionally, for every unit increase in access to lime input and general agricultural inputs, the probability of perception and adoption of lime technology increases by 24.9% and 11.1%, respectively.

Access to extension services (ACCTOEXT) was also found to significantly influence the probability of ag-lime technology perception and adoption by smallholder farmers at a 5% (P=0.046) probability level. This suggests that regular extension visits increase rural households' access to information, leading to better awareness of new agricultural technologies and innovations. As access to extension services increases by one unit, the probability of perception and adoption of lime technology increases by 51.5%.

Distance to markets (DISTOMKT) plays a crucial role in determining farmers' access to inputs, technology, and output markets. Farmers located closer to markets have better access to information about improved technology and can make early decisions regarding adoption. The result of the ordered probit model output shows that distance to market significantly influences farmers' perceptions of agricultural lime adoption at a 1% (P=0.000) probability level.

Similarly, distance to the agricultural office (DISTAGRI) impacts farmers' access to inputs, technology, and output markets. Farmers located closer to agricultural offices have better access to information about improved technology and can make early decisions regarding adoption. The ordered probit model output shows that distance to market significantly influences farmers' perceptions of agricultural lime technology adoption at a 5% (P=0.011) probability level.

Conclusion and Policy Implications

The objective of this study was to assess the perception and determinants of agricultural lime technology among smallholder farmers in Ethiopia, specifically in areas where major lime interventions have been implemented by research centres and other organizations. According to the descriptive results, most respondents agreed and had a positive perception of adopting agricultural lime technology to reclaim their acidic plots. However, the study identified four crucial challenges in the area: availability of lime, accessibility, sustainability concerns, and soil acidity testing services, in order of importance. The study suggests that there is a substantial and positive demand for lime technology, so the supply side needs to be strengthened by building the capacity of lime enterprises in terms of production, delivery facilities (warehouses), and transportation.

The ordered probit regression analysis identifies several key factors influencing farmers' perceptions and participation in lime technology use. The significant determinants include gender, education level, access to lime inputs, access to general agricultural inputs, access to extension services, distance to markets, and distance to agricultural institutions.

The findings suggest that farmers who are better educated, have improved access to lime and other agricultural inputs, and receive adequate extension services tend to have a more favourable perception of lime technology. Conversely, greater distances to markets and agricultural institutions negatively affect farmers' perceptions and willingness to adopt lime technology. These results lead to the following suggestions as a way forward:

1. Increase Access to Lime and Agricultural Inputs: Measures should be taken to make lime and other crucial agricultural inputs more widely available and reasonably priced. This can entail bolstering local facilities that produce lime, boosting supply chains, and offering financial incentives or subsidies to cut expenses.
2. Strengthen Extension Services: Farmers' adoption of lime technology can be strongly impacted by the growth and improvement of extension services. Farmers should be taught the advantages of using lime, as well as appropriate application techniques and management techniques, through extension programs. Addressing the gaps in knowledge and abilities could be especially successful with training and awareness efforts.
3. Lessen Distance Barriers: There is a need for efforts to lessen the negative effects of distance to agricultural institutions and markets. Reducing logistical obstacles and improving access to vital resources can be achieved by developing local marketplaces, bringing agricultural services closer to farmers, and improving rural road infrastructure.
4. Encourage Farmers to Have Better Access to Credit and Financial Services: Farmers who have better access to credit and financial services may be able to purchase lime and other inputs that are required for adoption. Financial institutions ought to think about creating lending solutions specifically designed to meet the requirements of smallholder farmers using lime technology.
5. Institutional Support and Policy Advocacy: Lawmakers ought to foster an atmosphere that facilitates the use of lime technology. This include creating regulations that facilitate input supply chains, lowering obstacles to entry, offering funding, and cultivating alliances with non-governmental and private sector entities.

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References

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

Achalu C., A., Gebrekidan, H., Kibret, K., & Tadesse, A. 2012. Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences*, *2*(3), 57-71.

Amede, T., Schulz, S., Warner, J., & Tefera, S. 2019. Managing acid soils for reclaiming livelihoods in Ethiopia. *CGSpace*.

ATA.2014. Soil Fertility Mapping and Fertilizer Blending. Agricultural Transformation Agency (ATA), Addis Ababa, Ethiopia.

Borooah V.K. 2002. Logit and Probit: Ordered and Multinomial Models. Quantitative Applications in the Social Sciences, No. 138. Thousand Oaks: Sage Publications.

Chen, J. H., Wu, J. T., & Huang, W. T. 2001. Effects of compost on the availability of nitrogen and phosphorus in strongly acidic soils. Ext. Bull., ASPAC Food Fert. Technol. Cent. (155).

CSA. 2018. Report on Area and Production of Major Crops. Agricultural Sample Survey 2017/18, CSA (Central Statistical Agency). Volume 1. Addis Ababa, Ethiopia.

Desalegen T., S. Indris, D. Abera, W. Tolcha, T. Hordofa. 2019. Proceedings of the Natural Resources Management Research completed Research activities Workshop (eds.), Addis Ababa, Ethiopia (2019) November 25- 26 at EIAR-HQ.

Getachew A., Temesgen D., Tolesa D., Ayalew A., Germew T. and Chilot Y. 2017. Effect of lime and phosphorus fertilizer on acid soil properties and barley grain yield at Bedi in western Ethiopia.

Gurmessa B. 2021. Soil acidity challenges and the significance of liming and organic amendments in tropical agricultural lands concerning Ethiopia Environ. Dev. Sustain., 23 : 77-99.

Haile, W., Boke, S., & Box, P. 2009. Mitigation of soil acidity and fertility decline challenges for sustainable livelihood improvement: research findings from southern region of Ethiopia and its policy implications. *Awassa Agricultural Research Institute*.

Ibrahim Ahmed 2012. Socio-economic impact of forage development on farm households livelihood in Mieso District, West Hararghe Zone, Oromia National Regional State (Doctoral dissertation, Haramaya University).

Kuma, M., & Redi, M., Wubayehu G/Medhin. 2018. Determinants of nitrogen and phosphorus rates for wheat under limed acid soils of Banja District, North Western Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa. Soil Fertility and Plant Nutrient Management, ISBN: 978-99944-66-52-8. 114-120. http://www.eiar.gov.et [Google Scholar].

Jha, S., Kaechele, H., & Sieber, S. 2019. Factors influencing the adoption of water conservation technologies by smallholder farmer households in Tanzania. *Water*, *11*(12), 2640.

Jha, S., Kaechele, H., Lana, M., Amjath-Babu, T. S., & Sieber, S. 2020. Exploring farmers' perceptions of agricultural technologies: A case study from Tanzania. *Sustainability*, *12*(3), 998.

Meijer S. S., D. Catacutan, O. C. Ajayi, G. W. Sileshi, and M. Nieuwenhuis. 2015. The role of knowledge, attitudes, and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa, International Journal of Agricultural Sustainability, 13(1): 40-54.

Mesfin, A. 2005. Analysis of the Factors Influencing Triticale Adoption and Their Impact Farta Wereda's Case. MSC. Thesis (unpublished) presented to Alemaya University's School of Graduate Studies.

National bank of Ethiopia 2021/22, Annual report

Oumer, A. M., Diro, S., Taye, G., Mamo, T., & Jaleta, M. 2023. Agricultural lime value chain efficiency for reducing soil acidity in Ethiopia. *Soil Security*, *11*, 100092.

Taha, M. 2007. The factors determine the adoption of an improved onion production package in the Dugda Bora district of East Shoa, Ethiopia. M.Sc. Thesis Presented to Haramaya University's School of Graduate Studies.

Tamene L., T. Amede, J. Kihara, D. Tibebe, S. Schulz. 2017. A Review of Soil Fertility Management and Crop Response to Fertilizer Application in Ethiopia: Towards Development of Site- and Context-specific Fertilizer recommendation. CIAT Publication No. 443 (eds.), International Center for Tropical Agriculture (CIAT) (2017) 86 p. Available at https://hdl.handle.net/10568/82996.

Tilahun T., Tadesse, Z., Asega, H., & Tafere, C. (2020). Optimum nitrogen and phosphors fertilizer rates for upland rice production in North Western Ethiopia. *Journal of Agriculture and Environmental Sciences*, *5*(1).

Warner J., C. Yirga, S. Gameda, S. Rashid, D. Alemu. 2016. Soil Acidity Problems in Ethiopia: Magnitude, Current Awareness and Practices, and Policy Actions. International Food Policy Research Institute (IFPRI), Washington, D.C (2016)

Warner, J. M., Mann, M. L., 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.

Zemarku, Z., Senapathy, M., & Bojago, E. 2022. Determinants of adoption of improved dairy technologies: the case of offa woreda, Wolaita zone, southern Ethiopia. *Advances in Agriculture*, *2022*(1), 3947794.

Zeleke, G., Agegnehu, G., Abera, D., and Rashid, S. 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. (I. F. P. R. I. (IFPRI), ed.), pp. 63, Washington, DC, USA.