

**Review Article**

Lime Technology Practices for Mitigating Soil Acidity in Ethiopia: A Review

Hana Amare

Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center, Holeta, Ethiopia

Email address:

hanaamare72@gmail.com

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Abstract: Soil acidity is a pressing issue in Ethiopia, more than 43% of Ethiopian farmland is affected by soil acidity problem where major staple food crops are grown, and it leads to significant crop yields reduction and in severe cases, may resulted in complete crop production loss and thereby contributed to food insecurity. The adoption of modern agricultural technologies remains a promising strategy to enhance agricultural productivity, achieve food security and reduce poverty in Ethiopia. Agricultural lime technology is widely considered as an effective remedy for amending soil acidity and increasing crop productivity. Lime technology is the one of the options to solve this problem and increase agricultural productivity by alleviating soil acidity problems. This review explores the extent of acid soil distributions in Ethiopia, its impact on crop production and lime technology practices as a viable solution to mitigate soil acidity. The paper presents an introduction to the problem, discusses various lime application methods, their effectiveness, considers the economic and environmental implications, and lastly summarizes the key findings, emphasizing the potential benefits of adopting lime technology in Ethiopian agriculture. Based on the keywords of this empirical review findings this paper suggested farmers should be encouraged to use lime technology, this would be attainable if the government, nongovernmental organizations, and other stakeholders focused more on providing the required lime, improving extension services and providing better information and training on the use and benefit of lime technology for acidic soils are some important ideas.

Keywords: Adoption, Determinants, Lime Technology, Soil Acidity

1. Introduction

Ethiopia faces a significant challenge in soil acidity, which hampers agricultural productivity. The problems of land degradation and low agricultural output resulted in food insecurity in the country.

The rural highlands of the nation are severely affected by the issues of land degradation and low agricultural productivity that lead to food insecurity and poverty [38]. Soil acidity affects huge parts of Ethiopia's highlands in practically all of its regional states. According to Ethio, S I S soil acidity affects 43% of Ethiopia's agricultural land [24]. Additionally Mesfin, notes that moderately acidic soils with a pH under 5.5 have a significant impact on crop growth and require intervention [43]. Climate factors like high precipitation (leaches significant amounts of exchangeable bases from the

surface soil), temperature, and severe soil erosion, as well as morphological and anthropological factors, are the main causes of increased soil acidity in Ethiopia. High-acid Nitsols make up the majority of the Western Oromia highlands' biggest areas [32].

Soil health and fertility have continued to be key aspects in boosting and maintaining agricultural yields to meet the rising demand for food and raw materials. To enhance agricultural output, this necessitates the right use of information about soil acidity and its amelioration. To boost the yields of their preferred crops on acidic soils, farmers need quick and lasting methods. With new advancements like liming, recommendations on acid soil reclamation need to adapt. By liming the soil or adding basic minerals to neutralize the acid present, soil acidity can be easily adjusted. The most effective way to achieve and maintain an ideal pH

for the growth of a range of crops has been proposed to be liming acid soil [53]. In Ethiopia, various policies, strategies and legislations have been formulated and implemented at both federal and regional level to facilitate the scaling up of agricultural technologies in general and that of agricultural lime in particular [56].

By enhancing the productivity of acid soils, significantly achieving food security, the national agricultural research system (NARS) in partnership with the Ministry of Agriculture (MoA) and regional bureaus of agriculture in Oromia Amhara, and SNNP as well as other various stakeholders have been testing, developing and promoting integrated soil fertility management practices suitable for the high rainfall, acid prone, farming systems of the highlands.

Among others, the application of lime is considered the main strategy for reducing soil acidity and increasing productivity. Consequently, Ethiopia put in place an acid soil reclamation system to ensure lime is produced and distributed to farmers and developed acid soil management packages and launched demonstrations to increase awareness and adoption of liming practices [6].

However, due to the minimal amount utilized, smallholder farmers in Ethiopia frequently embrace new agricultural technology at low and uneven rates. It was asserted that a variety of demographic, institutional, social, and economic variables contributed to the limited adoption of lime inputs [41, 11]. Because of this, the soil's productivity fluctuates, which results in inconsistent crop output [1]. Therefore the objective of this paper was to review the use of lime technology as a means to ameliorate soil acidity in Ethiopia.

2. Soil Acidity

Soil acidity is among the major land degradation problems, which is the outcome of a complicated series of natural and human-caused processes. Because of situations that worsen base element deficiency, phosphorus-fixation, and toxicities of aluminum, manganese, and hydrogen ions, affects plant growth. Applying nitrogen fertilizers or manure, especially those with high concentrations of ammonium or urea, is the principal source of acidic soil because nitrification produces hydrogen ions. Soil pH decreases as the acidity increases because pH expresses acidity [47]. About 50% of the world's potentially arable soils are affected by soil acidity [39]. Due to the leaching process of carbonic acid, soils naturally have a tendency to become acidic (CO_2 dissolved in rainwater).

According to FAO 40% of Africa's land resources are currently degraded [27], despite the fact that 83% of rural populations in Sub-Saharan Africa rely on the land for their livelihoods. In Ethiopia, land degradation is a serious problem that has a significant impact on agricultural productivity and rural livelihoods [15]. This problem is particularly severe in the highlands, which make up 44% of the nation's total area and are under heavy human and livestock pressure, 90% of the world's population resides there, together with 75% of the world's livestock and 95% of the cropland [8]. Generally, the effects of land degradation have affected many people's

livelihoods, financial security, and nutritional status in the nation [9]. Land degradation has a significant negative influence on biodiversity in addition to reducing the productive potential of agricultural land, rangelands, and forest resources [16].

2.1. Soil Acidity Extent and Distribution in Ethiopia

Acid soils are spreading and occupying larger area of cultivated land in Ethiopia. Different reports have indicated that there is significant soil acidity coverage in Ethiopia [34]. Predominantly acid-affected southern, north-western, south-western, and central parts of Ethiopia are characterized by high rainfall [44].

According to Ethio and Abu about 43% of the Ethiopian high lands are affected by soil acidity, of these about 28.1% of soils in Ethiopia dominated by strong acid soils (pH4.1-5.5) [24, 2]. The detrimental effects of soil acidity normally occur when the soil pH falls below 4.5. In the humid and sub-humid areas of Ethiopia, vast areas of land in the western, south-western, north-western and central highlands of the country which receive high rainfall are thought to be affected by soil acidity [43]. Nevertheless, moderately acidic soils (pH 5.5-6.5) are distributed throughout much of the rest of the country [30]. In Ethiopia, soil acidity is a problem that has not been addressed in depth. It is found that most of these soils have high rainfall in the highlands [21].

2.2. Cause of Soil Acidity in Ethiopia

Soil acidification is a multipart set of processes resulting in the formation of acid soil. In the broadest sense, it can be considered as the summation of natural and anthropogenic processes that lower the pH of soil solution [14]. Some of the causes of soil acidity could be a type of parent material, leaching of base forming materials from soils in high rainfall areas, removal of agricultural by products (crop residues) and continuous crop harvest (without proper fertilization), removal of cations and continues use of acid forming inorganic fertilizers make an important contribution to soil acidity development in most highland areas of Ethiopia. Generally high rainfall and leaching, acidic parent material, organic matter decay, and harvest of high-yielding crops are the major causes for soils to become acidic [12].

2.3. Effect of Soil Acidity on Crop Production

Nearly 50% of the world's currently arable soils are acidic, acidic soils severely restrict agricultural output worldwide. The main restrictions of acid soils are hazardous concentrations of aluminum (Al), manganese (Mn), and unsatisfactory concentrations of phosphorus (P) [39]. One of the barriers to crop production in acidic soils is the limited nutrient availability that comes with soil acidity, Because phosphate is the least mobile of the primary plant nutrients and can easily be rendered unavailable to plant roots at pH levels below 5.5 yields of crops cultivated in such soils are very poor [31].

Crop productivity is restricted or decreased by acidic soil

mostly because it hinders root development, which lowers nutrient and water uptake. A lack of or diminished reaction to ammonium phosphate and urea fertilizers, hindered root and plant growth due to the nutrient deficit (yields usually lowered by 50% and can be reduced to 0), and an increase in disease and toxicity are just a few effects of soil acidity on plant growth [26].

3. Soil Acidity Management

The goal of managing acid soils should be to increase their production potential by the use of amendments to correct the acidity and the manipulation of agricultural techniques to get the highest crop yield possible while the soil is acidic [6]. It is well known that lime (CaCO_3 or its equivalent) is an efficient ameliorant for reducing soil acidity. By liming the soil or adding basic minerals to neutralize the acid present, soil acidity can be easily adjusted [57]. Liming is a crucial technique for achieving the best yields for all crops grown on acidic soils; it is the most popular long-term technique for reducing soil acidity [25]. Liming is the application of calcium-and magnesium-rich materials to the soil in various forms, including marl, chalk, limestone, or hydrated lime. It is a desirable practice where the soil is highly acidic and multi-cropping involving acid sensitive-crops is adopted. Lime, in its most pure form, is made up largely of Ca. Calcium carbonate is a base, and therefore, has a neutralizing effect on acid [22].

The most economical method of ameliorating soil acidity is liming. The amount of lime needed will depend on the pH profile of the soil, the nature of the lime, the type of soil, the farming method and rainfall [33].

Agricultural research and development efforts in Ethiopia, as well as elsewhere in the world, indicated that a breakthrough in agricultural development in acid soil areas could be achieved by using agricultural lime. Various studies verified this and indicated that lime is necessary to obtain adequate crop yields in acid-prone areas. However, Ethiopia now uses relatively little lime to reduce soil acidity. Lime use is limited to around 5,100 ha as of the 2015 crop year, according to the MoANR. The Ethiopian government intends to expand the production, distribution, and promotion of lime by smallholder farmers, such efforts are expected to raise agricultural production and will have several benefits to the national economy [56].

3.1. Practice of Lime Technology in Acidic Areas Worldwide

South America, northern and eastern North America, South-East Asia, Central and southern Africa, northern Europe, and Eurasia are the regions with the highest concentration of acidic soils. Developing nations account for around 60% of the world's acidic soils, mostly in the tropics and subtropics [27]. In the agricultural zone of Western Australia (WA), more than 70% of top soils have a pH lower (i.e., more acidic) than the Department of Agriculture Western Australia (DAFWA) target of 5.5 and almost half of the sub soils have a pH lower than DAFWA's target of 4.8 [18]. The value of lost production in this area due to acidity has been

estimated at \$A1.6 billion year⁻¹ [37].

The most important crop in the WA agricultural zone, wheat, has a higher yield when lime is used, and the potential advantages from a widespread lime application are estimated at \$A63 ha⁻¹year⁻¹ [37]. According to the state of the environment report currently, 1 million tons of lime is sprayed annually in WA's agricultural zone; 2.5 million tons of lime will be needed yearly to meet soil pH goals in this region. The minerals lime-sand, coastal limestone and dolomite are frequently used to cure acidification in Australia [29]. Liming raises the pH of the soil and changes the make-up of the cation exchange complex. Before the 1960s, the vast inland cerrado region of Brazil was thought to be unsuitable for farming because the soil was too acidic and poor in nutrients, According to Nobel Peace Prize laureate and American plant scientist Norman Borlaug, who is known as the father of the Green Revolution, crops are deficient in nutrients, to counteract this, enormous amounts of lime (pulverized chalk or limestone) were added to the soil starting in the 1960s. As a result of continuous work, Brazilian fields were receiving between 14 million and 16 million tons of lime annually by the late 1990s. In 2003 and 2004, the amount increased to 25 million tons, or almost five tons of lime per hectare. As a result, Brazil is now the second-largest exporter of soybeans worldwide.

A single application of lime takes almost one year to achieve maximum effectiveness, and benefits can last six years or more [58]. Therefore, it is crucial to take into account how lime will continue to help crops from one crop season to the next. The ideal application rate and timing of lime should take this into account. In Zambia, Mulungu and Ng'ombe indicated that plots with lower-than-optimal lime application rates also produced greater yields than unlimed plots and were profitable due to high marginal rates of return indicating that improving lime uptake and, thus, increasing the yields and income of smallholder farmers [45]. Similar to this, the Indiana lime application research assessed the financial viability of lime application at a variable rate as a stand-alone activity.

Crop productivity is severely limited in the humid high-rainfall regions of SSA due to soil-acidity and more specifically the presence of relatively high levels of exchangeable aluminum (Al). Some strongly weathered soils, such as Ferralsols or Acrisols, which make up about 15% of the agricultural land in SSA (www.fao.org), are naturally acidic, whereas others, such as Arenosols or Lixisols, which make up about 27% of the agricultural land in SSA (www.fao.org), are susceptible to acidification as a result of ineffective management techniques, such as the application of ammonium-containing fertilizer. Since it limits the availability of many nutrients (such as P, Ca, and Mg) and slows root growth in most plants, Al toxicity is thought to be the main problem of acid soils rather than soil acidity peruse.

The best method for addressing Al toxicity is liming [40]. Nevertheless, there hasn't been much focus on Al toxicity management in recent years in SSA, primarily because the use of lime has been restricted by a lack of infrastructure for mining lime deposits and transporting the finished product,

and Al toxicity is thought to be localized to only a small number of areas of central Africa where highly weathered and leached soils occur [17]. Liming has been shown to boost the effectiveness of fertilizers primarily through enhancing nutrient availability by promoting processes that control nutrient release and availability in the soil solution and increasing the availability of nutrients via the soil and enhancing root growth. In conclusion, appropriate liming practices are expected to increase the agronomic efficiency of fertilizers on soils exhibiting high levels of exchangeable Al by favoring processes towards increased nutrient availability and uptake. Even though lime deposits are available in most countries affected by Al toxicity, the cost-effectiveness of lime application, especially in relation to transport and the commonly required high application rates, is likely to negatively affect the adoption of this practice [55].

3.2. Current Practice of Lime Technology in Ethiopia

Soil acidity and associated low nutrient availability are key constraints to crop production in acidic soils, mainly Nitisols of Ethiopian highlands. 43% of the Ethiopian cultivated land is affected by soil acidity [35, 10]. Liming acid soil is one of the most effective and widely used intervention techniques to reduce the effects of soil acidity and increase crop output [52]. Numerous writers have examined lime in relation to various crops. Studies on bread wheat at Gozamin, on barley at Bedi; on potato at Bedi, Holetta, and Cheha; are reported contribution of lime to enhanced Yield of tested crops [7, 42, 54]. By applying lime to barley fields on the Nitisols of Bedi, in Ethiopia's central highlands, increased grain yield by 274.0% in comparison to unlimed plots [7].

According to Agegnehu, Ghizaw, and Sinebo lime was applied at rates of 1, 3, and 5 t ha⁻¹, which considerably increased the production of faba beans by 45, 77, and 81%, respectively, above the control [5]. According to the study, the lime treatment caused soil pH to continue rising from 4.37 to 5.91 as lime the rate increased. In general, liming ought to be viewed as a soil supplement to increase soil pH to the level appropriate for maximum nutrient availability, plant growth, and crop yield. Increases in yield showed a clear relationship with soil pH levels.

Deressa, Bote, and Legesse claim that adding lime to the soil boosts agricultural productivity [19]. Only a small amount of grain yield was shown to be positively correlated with soil pH, which shows that as pH improves, the yield rises as well. It also suggests that as exchangeable acidity gradually decreases, plant root function is increased [32, 20]. Understanding soil pH is essential for the proper management and optimum soil and crop productivity.

Lime should be used to modify acidic soils, and soils with a pH of less than 5.5 should receive lime treatment. Based on suggestions from a soil laboratory, the CASCAPE project found that liming acid-affected soils in Dera (Sheme kebele) and Jabitehenan (Mana kebele) boosted food barley productivity. Consequently, food barley productivity has been improved by 50% with the application of lime.

According to the ministry of agriculture review on the

productivity and economic benefits of using agricultural lime policy document, reclaiming 1.37 million hectares out of the total 3.7 million hectares of strongly acidic soils would result in 21.9 million quintals of additional yield per annum from three major crops (wheat, maize and barley) grown in highland areas. However, attempts to increase the use of lime are anticipated to increase agricultural output and have a number of positive effects on the economy of the country. Beginning with the local, regional, and even national economic activity, the increase in net agricultural income would have an impact. The availability of agricultural products for domestic consumption and agro-industries would result from improved agricultural productivity, which is the second benefit. Third, greater export revenues are projected to result from expanded supplies of agricultural goods like soybean and faba bean. The import of fundamental agricultural products like wheat would decrease with increasing agricultural production, which would have a positive impact on food security and help conserve hard-earned foreign currency [6].

3.3. Factors Affecting Lime Technology Adoption in Developing Countries

Adopting more advanced agricultural technologies is a crucial step toward reducing poverty and ensuring food security in developing nations. For a variety of reasons, farmers find it challenging to embrace new agricultural technology, particularly when adoption is gradual and many adoption-related difficulties are poorly understood. Many academic articles explore numerous adoption detriments, such as the technology's nature, knowledge, risk aversion, institutional hindrances, lack of human and institutional resources, institutional hurdles financial resources, and a lack of infrastructure. The idea of adoption and dissemination has been extensively used to pinpoint the influencing factors that users consider when deciding whether to accept an innovation or reject it. Innovation is an idea, practice or object that is perceived as new by an individual [49].

The Farm Lime Project Summary Report lists the following as the primary factors that limit the adoption of agricultural lime: agricultural lime distribution and availability, In Zambia, there are a few numbers of centralized producers who primarily serve large-scale commercial farmers and are hesitant to provide the smaller numbers needed by small-scale farmers. Lack of emphasis on using agricultural lime, Farmers complained that agricultural extension staff gave them very little advice regarding the use of agricultural lime. This led to some farmers being unwilling to participate in the use of agricultural lime. Small-scale farmers need to be shown the advantages of agricultural lime. It was discovered that no soil testing is being done for the farmers in the Mkushi and Solwezi district areas due to a lack of infrastructure for soil sampling and testing. As a result, they are unable to determine the pH of their soil or the appropriate quantity of lime.

The decision to use lime is influenced by socioeconomic and biophysical considerations. Crop cultivated, soil type, starting pH, nitrogen fertilizer inputs, rainfall and soil

moisture, lime type and quality, and liming procedures are examples of biological influences [50]. The cost of purchasing lime at the quarry, the cost of carrying lime to the farm, the cost of spreading lime, the cost of incorporating lime into the subsoil, the cost of grains, and the farmer's discount rate are the main economic elements determining the economics of applying lime [51]. Lack of knowledge about the varieties and application methods of lime, as well as the distance to the source of the lime (connected to the cost of transporting the heavy and dusty product), are the main reasons for the low adoption of liming [48].

3.4. Factors Affecting Adoption of Lime Technology in Ethiopia

Several factors have been identified as the main constraints of the adoption of agricultural technologies by different scholars. These factors have been grouped into various categories by different researchers, grouped these factors into technological factors, economic factors, institutional factors and household-specific factors [46]. According to Ayenew the adoption rate of lime technology was low and affected by different factors, the binary logistic regression result of his study also indicated that; educational status, leadership status, economic level, family size, and access to extension contact were positive determinant factors in lime adoption. Whereas, age and farm size of the HHs were negative determinant factors in lime adoption [11].

Admassie and Ayele describe that younger farmers, farmers with larger land sizes farmers living closer to the market, and farmers who had closer contact with the extension system are more likely to adopt new technology and use it more [3]. Information is a crucial determinant of the adoption of a technology; the study has shown that the intensity of the use of improved technologies like fertilizer by farmers in Ethiopia is affected by household characteristics and the amount and type of resources owned by the farmers. The adopters of inorganic fertilizer were characterized by educated and slightly high resource endowment (labor, land and livestock) than non-adopters, access and availability of extension service to be more powerful than other factors in explaining adoption and intensity of inorganic fertilizer technology adoption [23].

According to studies, Ethiopia and the bulk of SSA countries utilize relatively little fertilizer [4]. Two groups in particular are specifically criticized by these authors for the low utilization. According to the first category of market-based restraints, farmers do not use inorganic fertilizer because of a high fertilizer to crop-price ratio. The second category of limits, known as non-market-based restrictions, focuses on farmers' lack of information regarding inorganic fertilizers and the degradation of the land, which lessens the advantages of applying fertilizer.

The qualities of the farmer, the farm structure, the institutional characteristics, and the management structure are the categories used to classify the elements influencing the adoption of agricultural technologies [13]. Evidence from earlier studies demonstrates the crucial impact that inadequate input supply and marketing systems have on the choices of

inputs and the adoption of technology in smallholder agriculture [13]. The availability of financing services, extension visits, and information sources may have an impact on how quickly farmers adopt innovations. Farmers that take part in workshops and field trips learn current, pertinent information about agricultural production, which may encourage them to use agricultural technology [36].

Age of the household head, education level, farm size, livestock holding, and availability to extension services, access to credit services, cooperative membership, and distance from the market were all strongly associated with the use of agricultural technology in Ethiopia [28]. A number of studies have generally been done on the factors influencing Ethiopia's adoption of agricultural technology. Their study revealed that Ethiopia was unable to implement novel and/or improved agricultural practices due to several factors, including socioeconomic, institutional, demographic, and psychological factors. The utilization of agricultural technology that was either already in use or being developed had therefore been impossible. These technologies would have assisted the nation or region in achieving.

4. Conclusion

Lime technology offers a promising solution to mitigate soil acidity in Ethiopia, enhancing agricultural productivity and food security. Different lime types and application methods provide flexibility to address specific soil conditions. However, successful implementation requires proper soil testing, lime quality control; identify technology adoption factors and farmer education. The economic benefits, including increased crop yields and reduced reliance on costly synthetic fertilizers, make lime technology a cost-effective and sustainable option. Furthermore, the environmental benefits of reduced nutrient runoff and lower carbon emissions contribute to the overall appeal of lime technology in Ethiopian agriculture. Embracing lime technology practices can lead to more resilient and productive agricultural systems, ultimately improving the livelihoods of Ethiopian farmers.

Availability of Data

Data is not available.

Conflicts of Interest

The authors declare no conflict of interest in the manuscript.

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