Investment Case for Agricultural Lime in KENYA

August 2023

CIMMYT | CGIAR

BILL & MELINDA GATES foundation

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Contents

Abbreviations and Acronyms

AGRA	Alliance for a Green Revolution in Africa
CIMMYT	International Maize and Wheat Improvement Centre
KALRO	Kenya Agricultural Livestock and Research Organizations
PLNT	Plantain

I. Executive Summary

Lime presents the most viable solution to treat soil acidity. Soil acidity currently affects 13% (7.5 M ha) of Kenya's cropland**.** Acidic soils hamper crop production and hence, are a major cause of crop yield reduction and, consequently, reduced agricultural incomes. Agricultural productivity for smallholders has stagnated in recent years: (i) crop yield per ha, particularly for staples that guarantee food security such as maize, beans, millet, potatoes, and wheat are on the decline;[1] and (ii) earnings from cash crop are under pressure with three of the leading export earners for Kenya in coffee, flowers, and vegetables facing decreasing yield. Among the available solutions to treat soil acidity[2], lime proves to be the most effective approach to achieve efficient agricultural output, due to its ample local availability, effectiveness (lime in Kenya has a high concentration of calcium carbonate), impact on soil properties, and, as the lime industry grows, is the most affordable option at scale.

However, determining the actual benefit of lime is challenging due to a host of interlinked factors. The lack of authoritative information on liming practices limits the effectiveness of lime. In Kenya, lime application practices are unharmonized with no authoritative source on the best practice application methods nor the benefits of lime. Similarly, existing literature on agricultural lime states that response time of lime can vary between six months to over three years, depending on soil properties, level of acidity, and the type of crop. This is further compounded by the inconsistency in the quality of lime. The inconsistent quality of lime is driven by two factors: low demand which disincentivizes manufacturers on improving quality and limited quality checks on lime as it's mainly collected as a by-product from cement manufacturers. These interlinked dependencies result in minimal adoption of lime by farmers.

To realizing the economic opportunity for lime, it is important to identify the right 'nodes of entry' that can provide benefits both to farmers and lime producers. The nodes of entry are defined as regions and crops that are likely to generate the highest economic surplus to farmers due to lime application and can serve as proof of concept for scaling lime across the country in the future. In Kenya, these regions are Western and Central region. The Western region is made up of Bungoma, Busia, Kakamega, and Trans Nzoia counties while the Central region is made up of Meru County. Each of these regions have distinct crops that provide the highest economic surplus to farmers.

In the Western region, sweet potato, potato, banana, ground nut, and PLNT have the highest economic potential, based on the usage of lime. Adding lime to acidic soils in these clusters can generate an additional revenue of 22.16 million USD for farmers.[3] The region has about 130,000 ha of cropland that is highly acidic (pH<5.5).[4] However, the target clusters are of much lower acreage, translating to a total need for lime of 45,686.81 MT annually. The economic surplus generated for farmers due to the use of lime is 14.77 million USD. This is largely attributed to the high price of the target crops relative to the price of lime and moderate amounts of lime required that lower costs. **Sweet potato, potato, banana, ground nut, and PLNT** can yield extra production quantities of 1.05, 0.75, 0.99, 1.80, and 2.13 MT/ha respectively when acidic soils are remediated with lime. While the extra production quantities are low, the prices of **sweet potato, potato, banana, ground nut, and PLNT** per metric ton are more than 2 times greater than the price of lime which primarily drive the high economic surplus.[5] **Sweet potato, potato, banana, ground nut, and PLNT provide total economic surplus (USD by the third year) of 9.80 million, 3.97 million, 950,391.80, 49,860.52, and 171.72, respectively.**

1 Soil Sustainability Evaluation of Maize production in Kenya

2 Other solutions include fertilizing residual materials, acid-tolerant seeds, and bio charcoal. Refer to the Lime Sector Analysis Report for Kenya for further details

3 Considers a residual effect of 50% in year 2 and 25% in year 3 after applying lime

4 GAIA, Ex-ante analysis, 2021

5 CIMMYT, Economic surplus analysis for Crops, 2022

In the Central region, potato, and sweet potato generate the highest economic response to lime application. Remediating acidic soils with lime in these clusters would generate an additional revenue of 1.25 million USD to farmers. The total acidic area in Meru County is 30,000 ha. However, the target clusters are of much lower acreage, translating to a total need for lime of 1,418.27MT annually. The economic surplus generated due to the use of lime is about 1.02 million USD attributed to the high price of the target crops relative to the price of lime and with moderate lime requirements. In the region, potato, and sweet potato have extra production quantities of 0.06 MT/ha, and 0.1 MT/ha respectively. However, the prices of potato, and sweet potato per metric ton are 429.85 USD, , and 290.7490 USD respectively – more than two times higher than cost of lime per MT - which drives the high economic surplus derived by farmers - especially for potato which has low extra yield but a high market price.

The key constraint to the adoption of lime in the Western region is high farmgate prices, that, are primarily driven by inefficient production due to limited demand. Production capacities in the Western region are unutilized. Homa Lime, the main lime producer in the region, has a capacity of 36,500MT and is located about 110 km from the key counties.[6] However, its current annual production lies at 7300MT.[7] Price reduction will be key in generating greater demand for lime and thereby scaling lime in the region.

The main barriers to adoption of lime in the Central region are high distribution costs and insufficient supply. The closest manufacturer, ARM Cement, is 300 km away with lime which increases the total farmgate price of lime by USD 43. Farmers in the region also have limited access to lime. Lime is mainly accessed through agro-dealers. However due to the bulkiness of lime and general low demand in the region, few agro dealers stock it.[8]

To unlock the opportunities in these target markets, challenges need to be addressed across demand, supply, and enabling ecosystems to scale the adoption of lime. To increase demand, the provision of subsidies or lower cost credit facilities would make lime more affordable to farmers and help increase uptake, particularly in the Western region. Targeted awareness drives, focused on areas with the highest soil acidity, should be prioritized. Increased soil testing by county governments can help raise awareness on soil acidity and provide tailored recommendations on lime use. On the supply side, aggregating demand for lime at the farmer level, through cooperatives, can help increase bargaining power for farmers, enabling farmers to negotiate favorable prices for lime and improved last mile access / lower distribution costs. Similarly, increasing access to finance, generating favorable national agricultural lime policy, and building the evidence base of the use of lime in untested regions is required to scale lime adoption.

Upstream solutions also need to be taken into consideration to limit the spread of acidic soils. This entails the promotion of non-acidifying fertilizers such as Single Super Phosphate (SSP), Calcium Ammonium Nitrogen (CAN), and Nitrogen Phosphorous Potassium (NPK), and Mavuno (crop specific blended fertilizers).[9] This can be achieved by working with fertilizer manufacturers and agro dealers to promote the use of non-acidifying fertilizers and driving awareness among farmers on the effects of acidifying fertilizers on soils and crop yields. However, there are tradeoffs to using non-acidifying fertilizers such as higher transport and labor costs. Such fertilizers have a higher application rate as they require more quantities to provide the same amount of nitrogen as acidifying fertilizers such as Diammonium Phosphate (DAP) and urea which have higher nitrogen concentrations.

While the study of lime and its effects on crop yield in Kenya is in its infancy, this study acts as a starting point to aggregate efforts around developing demand and establishing supply for lime in Kenya. As a first step, we recommend **piloting activities in the target regions** to establish a proof of concept on the use of lime. Secondly, further **research needs to be conducted on crop yield response** to lime in various regions and crops that could provide recommendation on the use of lime. All these can culminate into the development of a **national investment plan** that would provide a detailed market sizing for lime, assess the supply and demand subsidies needed, provide timelines, and highlight the opportunity cost of investing in lime.

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6 Google maps, Distance from Homa Lime to key counties

7 Interview with Homa Lime General Manager

8 Kenya Market Trust, Economics of Granulated Lime, 2021

9 Mavuno planting fertilizer formulation: 10:26:10 + Calcium, Magnesium, Sulphur, Zinc, Copper, Manganese Boron, Molybdenum

II. Defining The Challenge

Soil acidity in Kenya threatens the country's food security. Currently, 13% (7.5 million ha) of Kenya's cropland is acidic, and solutions to treat soil acidity remain out of reach for most farmers.[10] Soil acidity is concentrated in the Central, Western, Lake Basin, and Rift Valley regions, the main food baskets for Kenya. Central Kenya is the main region to produce coffee, tea, beans, and wheat; sugarcane and maize are primarily produced in the Western region; maize, tea, and wheat are grown in Rift Valley regions; and the Lake Basin is the main region for sugarcane and millet.[11] The level of soil acidity is likely to worsen due to increasing fertilizer use and soil leaching. The use of Diammonium Phosphate (DAP) and urea have been blamed for increasing soil acidity, but farmers have shown little interest in alternatives, arguing they give better yields. This is because DAP and urea have a higher concentration of nitrogen, a critical element for plant growth, compared to blended fertilizers.[12] With continued use of such fertilizers, soil acidity is expected to increase.[13]

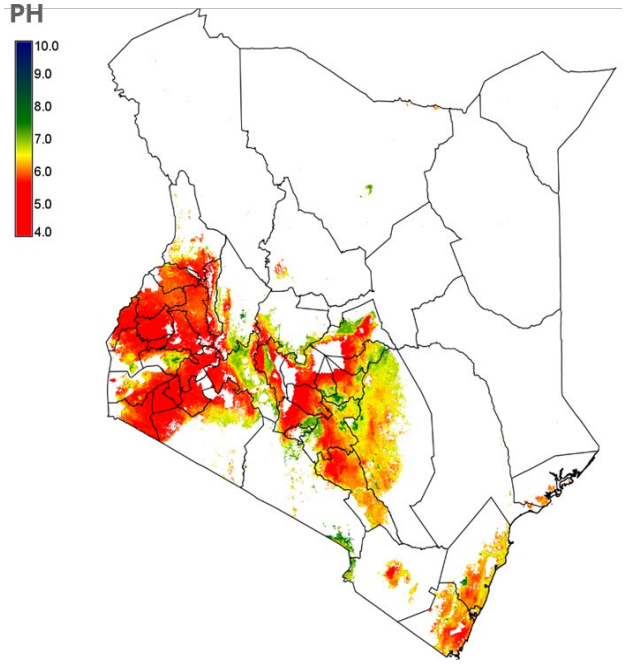


Figure 1: Soil acidity map of Kenya[14]

Lime provides the most effective and accessible approach to treating soil acidity, due to its ample local availability, effectiveness (lime in Kenya has a high concentration of calcium carbonate), impact on soil properties, and, as the lime industry grows, is the most affordable option at scale.

However, varying challenges in demand, supply, and the enabling environment constrain the development of the lime industry. Demand constraints include limited farmer awareness on soil acidity leading to low lime demand and high farmgate prices driven by high distribution costs. On the supply side, lime producers face sub-optimal and seasonal production challenges; distributors incur significantly high distribution costs and there is a lack of adequate and efficient storage facilities due to bulkiness and dustiness of lime. There are also limited policy initiatives from the government for lime as compared to fertilizer, with most initiatives focused on the demand side, by the development sector. Financing is a significant barrier, with high interest rates and long-term due diligence processes limiting access to capital. Figure 2 below shows a summary of the constraints in the three-tier framework.

The "right intervention point" requires solutions that address challenges across the lime value chain including the enabling environment. Demand side interventions include targeted awareness drives in highly soil acidic regions through farmer education programs and provision of subsidies to reduce the price of lime and drive demand. In parallel, supply side actors can explore options for improving the commercial viability of supplying lime through partnerships and optimization at

[10] Enhancing market access and use of agricultural lime amongst small holder farmers in Western Kenya: Early Impact Assessment Report
[11] Local and regional variations in conditions for agriculture and food security in Kenya, pg. 7
[12] Business Daily, Soil acidity spells doom for future of Kenya agriculture, 2019
[13] Soil Sustainability Evaluation of Maize production in 20% Kenya. Pg. 7
[14] CIMMYT, Gaia Ex-ante analysis, 2021

Binding constraints	Rationale
Demand 	• **Limited demand is the key binding constraint** to the supply of lime in Kenya. This limited demand is driven by two main key factors: - Prohibitive costs of lime due to high logistics cost of distribution and storage - Lack of awareness of timing, quantity, application method and yield response of lime
Supply 	• **Manufacturing is complex** due to unutilized capacity and surges in demand mainly due to: - Seasonality of demand as most of the lime is purchased during the rainy season at point of planting - Lack of adequate demand from farmers despite having adequate machinery for production • **There is inconsistency in the availability, price and quality of lime** across different distributors mainly due to: - No price regulation across an extremely margin sensitive distribution chain - No quality regulation for the standard of lime produced - Lack of availability in some areas due to bulkiness of lime needing too much space and dustiness in the storage spaces
Enabling environment 	• **Unregulated standards for lime production, distribution and sales** has led to the proliferation of inconsistent quality in the market • **Incoherent tax policy** that drives up cost of machinery for lime and cost of imported granulated lime • **Investments from traditional lenders are not suitable** for the lime sector due to: - Most financial institutions having high interest rates at >14% and are not patient - Slow to release capital for lime capex due to long due diligence processes • **Inappropriate use of lime due to unharmonized, multiple and conflicting sources of information** on soil acidity and the appropriate benefits and use of lime

the level of quality and cost. It is important to note that there is likely to be a limited desire to invest in solving supply-side challenges without increased demand. Identifying appropriate pathways towards commercial viability requires addressing the gaps in access to finance and policy. Complementary interventions to improve access to finance and the policy environment and demand and supply side interventions are key to growing the lime sector.

III. Identifying Priority Markets

Our approach to building an investment case for lime is anchored on the need to identify nodes of entry that are likely to move the needle in terms of economic benefit of lime for suppliers and farmers. Nodes of entry are defined as areas with crops that are likely to generate the highest economic surplus with lime application and can serve as proof of concept for scaling lime uptake across the country in the longer term.

Economic surplus can be defined as the extra financial benefit derived from applying lime after taking into considerations costs. Economic surplus is defined below in figure 3.

This study primarily focuses on economic surplus achieved within one growing season to articulate the demonstration effect and simplify assumptions such as the time value of money for the poor. However, it is important to note that liming has multi-year benefits.

To calculate economic surplus and identify the nodes of entry, we used a two-step process:

STEP 1: SELECTION OF RELEVANT CROPS

Relevant crops are prioritized based on yield response to lime and market price, in relation to the current price of lime. Relevant crops are defined as crops grown at scale, those aligned with government priorities, and cash crops with high potential for scale. To identify relevant crops, CIMMYT and Dalberg leveraged pixel level (approx. 1 km) data for each country which specifies a function for lime needed and potential yield benefits (on both aluminum toxicity and pH) for 26 crops. **Regions and crops for liming were only considered where economic surplus was greater than zero**. This allows for an investment case based on the potential for economic surplus.

STEP 2: DEFINING THE ECONOMIC CASE FOR LIME

The economic surplus due to lime application on shortlisted crops is calculated and used to create heat maps to identify the highest potential economic value regions. As shown in Figure 3, the economic surplus calculates the return on investment for a farmer (per MT) due to the application of lime by considering yield increases and translating that to net monetary returns.

Note: Consequently, we calculated the surplus potentially accrued in future years as lime takes time to completely react with soil and change soil properties. Lime typically reacts completely with the soil in two to three years after it has been applied. The length of time for complete reaction depends on the kind of lime used, total soil acidity, amount of organic matter, type and amount of clay, and cropping and management systems used. To accommodate for this, we used a discount rate of 50% in year 2 after lime application and 25% in year 3 after lime application. Similarly, the crops were selected based on currently available yield response data and show the economic surplus of lime application in target regions. With additional yield response data, the analysis can be repeated to determine the economic value of using lime on other crops with initial demand for lime such as avocado.

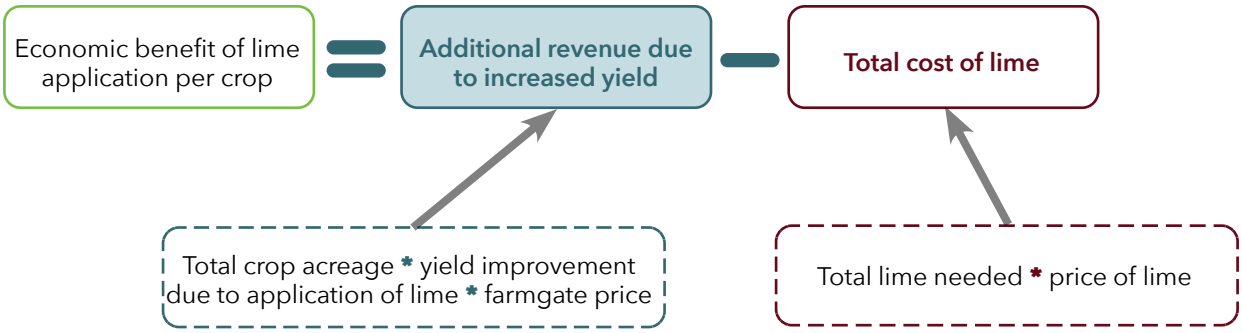
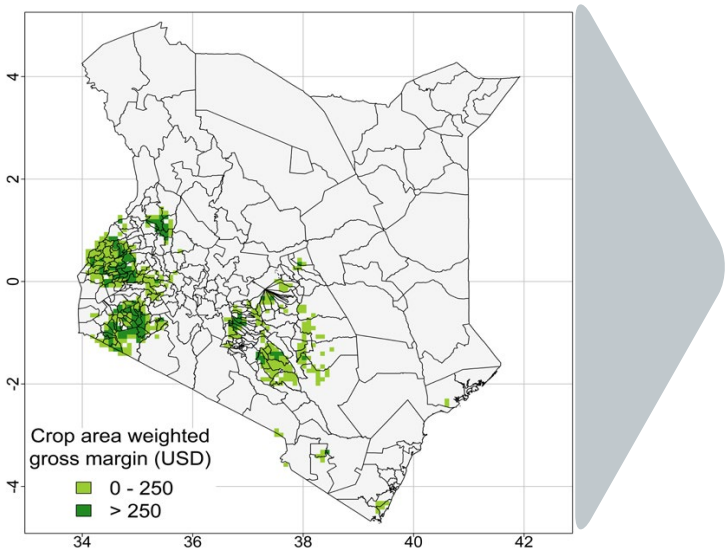


Figure 3: Economic Surplus Formula

The economic surplus maps are used to identify the highest economic value regions, which, combined with relevant crops, enable the identification of target markets for lime. In most regions, areas with moderate lime requirements have the greatest economic returns because soils need to get passed a certain absolute threshold of pH and aluminum toxicity before effects of liming are observed. Hence, the highest economic value is in areas where this threshold can be achieved, with a more modest quantity of lime.

This approach enables us to size the overall economic benefit of lime, in relevant regions, for lime producers and farmers. The primary benefit for both lime producers and farmers is financial.

Assuming the potential demand reflected in the market, lime producers are incentivized to improve production capacity to reduce the cost of production. Assessment of current realities in the production and distribution of lime is required to pinpoint supply side interventions needed to ensure adequate quality of lime, at an appropriate price to farmers, based on the expected economic surplus. On the demand side farmers can generate additional income due to improved crop yield and reduced price of lime. This develops proof of concept for other regions, leading to an increased uptake of lime in soil acidic areas, particularly if developing these markets increases efficiency of production and allows for the price of lime in the country to come down.



Western region

County:

- **Busia, Bungoma, Kakamega, Trans Nzoia**

Key crops:

- **Sweet potato, potato, banana, ground nut, PLNT**

Central region

County:

- **Meru**

Key crops:

- **Potato, sweet potato**

Figure 4: Highest economic value areas and crops in Kenya

IV. Economic Opportunity For Lime

The Western and Central regions provide the greatest economic opportunity to increase productivity for farmers by using lime. A series of conditions make these two regions the most feasible areas for lime investment. The regions have an annual demand for lime of 47,105.08MT translating to a total market size of 4,710,508 USD for lime producers. The regions also provide an economic surplus of 14.77 million USD and 1.02 million USD, respectively.

Opportunities in the Western region

The Western region is distinctly made up of four counties: Bungoma, Busia, Kakamega, and Trans-Nzoia counties. They account for 19% of food produced in the country[17] and cover about 9,400 sq km, translating to 2% of the total area in Kenya.[18] The region has a population of 5.4 million people, accounting for 11% of the Kenyan population.[19] It has a concentration of about 835k farmers[20] and agricultural output from the Western region accounts for 21% of Kenya's GDP.[21] Major crops grown in the region are sugarcane, maize, and beans.

The Western region has a total cropland area of 740,000 ha[22] - 17% is highly acidic (pH<5.5).[23] The total need for lime in the discrete clusters is about 45,686.81MT annually.[24] The key crops that generate the highest economic value to farmers are sweet potato, potato, banana, ground nut, and PLNT.[25] Applying lime to sweet potato, potato, banana, ground nut, and PLNT can generate an additional revenue of 22.16 million USD (by the third year) for farmers.[26] Taking costs into consideration, these crops can generate a high economic surplus of 14.77 million USD (by the third year) for farmers that is attributed to the high price of the target crops relative to the price of lime and the modest amounts of lime required reducing costs. In this region, sweet potato, potato, banana, ground nut, and PLNT can yield extra production quantities of 1.05MT, 0.75MT, 0.99 MT, 1.80 MT, and 2.13 MT respectively when acidic soils are remediated with lime. While the extra production quantities are low, the prices of sweet potato, potato, banana, ground nut, and PLNT per metric ton are USD 290.7, USD 429.85, USD 454.9, USD 619.45, and USD 257.5respectively which are more than two times greater than the price of lime.[27]

Table 1: Summary of economic opportunity for lime in the Western and Central Region

	Western province	Central province
Total market size for lime (MT)	45,686.81	1,418.27
Total market size for lime producers (USD)[15]	4,568,681	141,827
Total economic surplus (USD)[16]	14,769,762	1,023,494

[15] Calculation assumes cost of lime is USD 100 /Mt
[16] CIMMYT, 2022; Note: calculations are based on the sum of the first three years of surplus
[17] Kilimo Data, Crop production by counties 2019, Accessed March 2022
[18] Ministry of Devolution, Accessed May 2022
[19] Kenya Population and Household Census, 2019
[20] Ibid
[21] Kenya National Bureau of Statistics (KNBS), GDP by County, 2017
[22] CIMMYT, GAIA ex ante analysis, 2021
[23] CIMMT, GAIA ex-ante analysis, 2021
[24] CIMMYT, Crop response to lime based on exchangeable acidity, 2022
[25] Crop yield responses to lime are still being investigated and this data point can be refined with further research
[26] Considering a residual effect of 50% in year 2 and 25% in year 3 after applying lime
[27] CIMMYT, Crop response to lime based on exchangeable acidity, 2022

Table 2: Crops with the highest economic surplus in Western region[28]

Metric	Crops				
	Sweet potato	Potato	Banana	Ground nut	PLNT
Current area under production (ha)	31,099.08	9,062.51	2,367.11	161.38	6.8
Yield response to exchangeable acidity (MT/ha)[29]	1.05	0.75	0.99	1.80	2.13
Total demand for lime (MT)	34,661.04	4,636.72	4,859.21	1,493.56	36.28
Market price (USD/MT)	290.7	429.85	454.9	619.45	257.5
1st year total additional revenue (USD)	9,498,367	2,911,013	1,071,203	180,061.7	3,733.75
Total additional revenue by the third year (USD)	15,400,000	4,726,957	1,739,439	292,387.6	6062.93
Current cost of lime at the farmgate (USD/MT)	100	100	100	100	100
Total cost of lime needed in the 1st year (USD)	3,466,104	463,672	485,921	149,356	3,628
Economic surplus within one year (USD)	6,032,263	2,447,341	585,282.1	30,705.72	105.75
Total economic surplus by the third year (USD)	9,795,300	3,974,038	950,391.8	49,860.52	171.72

The region has sufficient lime production capacity to meet demand. The total demand for lime needed to remediate acidic soils and provide economic return to farmers in the Western region is 45,686.81 MT.[30] The main lime producer in the region, Homa Lime, has an annual capacity of 36,500MT and is on average about 110 km away from each key county.[31] This means that Homa Lime has the capacity to meet 79.89 % of additional lime demand[32] – and distribution costs can be kept low.[33] The remaining unmet demand for lime and a potential further increase due to wider adoption of lime in the region can be addressed through increased supply by making additional investments and moving production from an 8 -hour cycle to a 24-hour cycle. This would increase the supply of lime to 110,000 MT annually. This would require additional labor and potentially adding production equipment as back up in case of machinery failure. The region also has a vast lime deposit, Koru lime deposit in Kisumu, of 65 million MT of limestone that can be utilized for the next 800 years.[34]

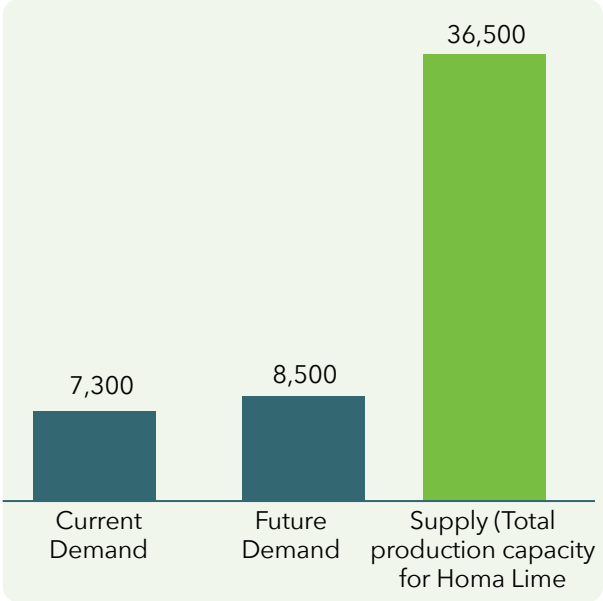


Figure 5: Annual demand and supply of lime in Western region[35]

[28] Ibid
[29] CIMMYT, Crop yield analysis based on exchangeable acidity (Hp), 2022. The crop response to lime is negligible, hence the economic surplus is driven by the prices for the Ag commodity
[30] This is anecdotal based on CIMMYT's crop analysis
[31] Interview with Homa Lime General Manager, 2022
[32] Ibid
[33] The cost of distribution per km is USD 0.12 translating to a distribution cost of ~KES 1200 to each county
[34] Ibid
[35] Ibid

The key constraint to the adoption of lime in Western region is high farmgate prices, that, are primarily driven by inefficient production due to limited demand. Currently, Homa Lime sells its lime for about 50 USD per MT [36] but due to distribution costs, the final farmgate price in the region would be ~ 62 USD per MT.[37] When compared to the average farmer income of 126 USD per month, the cost of lime is approximately 50% of their income making lime unaffordable.[38]

> *"We have been told that lime can help us to increase our yields, but our pockets do not permit"*
>
> **- Mr. John Bosire, a farmer whose soil is highly acidic**

Figure 6: Insights from farmers[39]

Numerous projects have been conducted resulting in a proof of concept, however, the price of lime continues to be a significant barrier to uptake. For example, AGRA through its Soil Health Programme 1, provided a joint research grant to KARI/KARLO and Moi University to train extension workers and agro-dealers, purchase vehicles, and buy lime for sale at subsidized prices.[40] Phase I of this project included farm demonstrations where selected farmers were each given 10 bags (500kg) of lime for free. This resulted in an increase in maize yields by up to 1.5 tons per ha. However, Phase II of the project, focused on supporting agro-dealer to stock lime, supplied from Homa Lime, to sell at subsidized prices to the farmer. While farmers bought lime at the subsidized price, fewer farmers applied the lime unlike in Phase I when lime was provided free of charge.[41] This left agro-dealers with huge stocks that were later turned over to the county government.

The Western region has been a key region of focus when conducting lime trials with numerous stakeholders working towards proving the case for lime and scaling adoption. In 2015, One Acre Fund conducted soil acidity trials in this region to determine the impact of using lime on crop yield and farmer revenue. The trial results were inconclusive as they did not show a correlation between lime use and crop yield.[42] Even after trial, the lime adoption rates remained at or lower than 3% primarily driven by lack of knowledge on the benefits of lime in treating soil acidity.[43] At the time, One Acre Fund provided 0.2 ha agricultural package that costed 100 USD that consisted of fertilizers, seeds, and lime. KARI/KALRO has also implemented lime projects in Kakamega and Bungoma county between 1990 and 2010 in collaboration with AGRA and universities. The EU Project on Cereals Enhancement Programme (KCEP) was implemented in 13 counties including Kakamega and Bungoma. Kakamega county Government has also supported soil testing efforts for the whole county in collaboration with AGRA.[44]

While the economic case of lime has been proven to both farmers and lime producers, reducing the price of lime will be key in scaling the uptake of lime in the region. Specific interventions to scale the use of lime in the region are discussed in the next chapter.

Opportunities in the Central region

The Central region is made up of Meru County. Meru County accounts for 5% of food produced in the country.[45] The county covers about 6,930 sq km accounting for 1% of the total area in Kenya.[46] The region has a population of 1.5 million and accounts for 2% of the Kenyan population.[47] The region is primarily driven by agriculture and contributes 8% of Kenya's GDP.[48] The major crops grown in the region are maize, wheat, millet, sorghum, tea, and coffee. The region also has a concentration of about 220k farmers.[49]

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36 Ibid
37 Dalberg Analysis, 2022
38 Dalberg and CIMMYT, Lime Sector Analysis in Kenya, 2021
39 Daily Nation, Acidic soils deal blow to food security efforts, 2019
40 KALRO and CIMMYT, Kenya Value Chain Analysis, 2022
41 The fact that powdered lime is dusty and tedious to apply coupled with the lack of mechanized lime applicators is a major challenge that discourages lime use at the farm level
42 The trial produced variable yield responses ranging from 1 to 41% and depending on soil conditions. This made establishing a relationship between lime application rate and crop yield response difficult
43 One Acre Fund, Managing Soil Acidity, 2015
44 Ibid
45 Kilimo Data, Crop Production in Kenya 2019, Accessed March 2022
46 Ministry of Devolution, Accessed May 2022
47 Kenya Population and Household Census, 2019
48 Kenya National Bureau of Statistics, GDP by County, 2017
49 Ibid

Meru County has a total cropland area of 270,000 ha[50] - where 11% is highly acidic (pH<5.5). The total need for lime in the target cluster is 2,200 MT.[51] The key crops that generate the highest economic value to farmers are potato, and sweet potato. Applying lime to potato, and sweet potato can generate total additional revenue of 1.25 million USD (by the third year) for farmers.[52] These crops generate an economic surplus of 1.02 million USD (by the third year) largely attributed to the high price of the target crops relative to the price of lime and the moderate amounts of lime required to treat the soil. In the region, potato, and sweet potato have low extra production quantities of 0.06MT, and 0.1MT respectively. However, the prices of potato, and sweet potato per metric ton are 429.85 USD, and 290.7 USD respectively which drives the high economic surplus derived by farmers - especially for potato which has low extra yield but a high market price.[53]

Table 3: Crops with the highest economic surplus in Central region[54]

Metric	Crops	
	Potato	Sweet potato
Current area under production (ha)	27,758.93	562.02
Yield response to exchangeable acidity (MT/ha)[55]	0.06	0.10
Total demand for lime (MT)	1345.45	72.82
Market price (USD/MT)	429.85	290.7
1st year total additional revenue (USD)	755,023	17,104.79
Total additional revenue by the third year (USD)	1,226,020	27,775.07
Current cost of lime at the farmgate (USD/MT)	100	100
Total cost of lime needed in the 1st year (USD)	134,545	7,282
Economic surplus within one year (USD)	620,478	9,822.79
Total economic surplus by the third year (USD)	1,007,544	15,950.43

The region has insufficient supply of lime to meet the potential demand for lime. The total potential demand for lime needed to remediate acidic soils and provide economic return in the target clusters is 1,418.27 MT. However, the region doesn't have any mapped lime deposits with closest lime manufacturer, ARM Cement, located 300 km away in Machakos County.[56] While ARM cement has sufficient capacity to meet the lime demand, the distribution costs can increase the lime farmgate price by 45 USD.[57]

The region has high awareness levels on lime; however, high distribution costs and insufficient supply are the main barriers to adoption of lime in the region. The closest manufacturer is 300 km away which significantly increase the end user price as distribution costs are high. Based on the Kenya Market Study report, the Mt. Kenya region, which Meru county is part of, has a high awareness of lime with 53% of respondents for the report having knowledge of lime but only 1.5% of the respondents had access to lime.[58] The high awareness levels in the region are attributed to the role of coffee cooperatives in educating farmers about lime.[59] Limited access of lime in the region is driven by low demand coupled with insufficient storage capacity by agro dealers due to the bulkiness of lime.

As the region isn't a key focus region for lime researchers and stakeholders, limited trials in the region have been conducted resulting in limited knowledge on crop yield response due to the application of lime. However, lime studies have been conducted in adjacent regions such as Embu, Tharaka Nithi, Nyeri, Kirinyaga, and Muranga counties.[60]

To scale the use of lime, wholesome interventions are required in the region across the lime value chain. Specific interventions in this region are discussed in the next chapter.

50 CIMMYT, GAIA ex ante analysis, 2022
51 CIMMYT, Crop response to lime based on exchangeable acidity, 2022
52 Considering a residual effect of 50% in year 2 and 25% in year 3 after applying lime
53 Ibid
54 Ibid
55 CIMMYT, Crop yield analysis based on exchangeable acidity (Hp), 2022. The crop response to lime is negligible, hence the economic surplus is driven by the prices for the Ag commodity
56 Google Maps, Distance from Athi River to Meru County
57 Assumes a distribution cost of USD 0.12/km
58 KMT, Market and Economic Feasibility of Granulated Lime in Kenya, 2021
59 Ibid
60 Ibid

Key sensitivities

The price of lime is a key factor influencing the economic surplus to the farmer. A decrease in the price of lime marginally increases the economic surplus derived by farmers.

Western region

On average, a 20% decrease in the price of lime leads to a 9.9% increase in the total economic surplus generated from liming of sweet potato, potato, banana, ground nut and PLNT in the Western region.

On crop-by-crop basis, a decrease in the cost of lime by 20% increases total economic surplus (by the third year) from sweet potato, potato, banana, ground nut and PLNT by 11.28%, 3.79%, 16.61%, 97.28%, and 686.96%, respectively.

Central Region

On average, a 20% decrease in the price of lime leads to a 4.5% increase in the total economic surplus generated from liming of potato, and sweet potato in the Central region.

On crop-by-crop basis, a decrease in the cost of lime by 20% increases total economic surplus (by 3 year) from potato and sweet potato by 4.34%, and 14.83%, respectively.

To increase the economic surplus generated by farmers, interventions need to be aimed at reducing the farmgate price of lime through including farmer subsidies and manufacturing subsidies.

Table 4: Effect on decreasing the price of lime by 20% on total economic surplus in Western region

	Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Total economic surplus by year 3[61]	14.77 million	16.23 million	9.9%

Table 5: Effect on economic surplus by decreasing the price of lime for sweet potato, potato, banana, ground nut and PLNT

		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Sweet potato	Total economic surplus by year 3	9,795,300	10,900,000	11.28%
Potato	Total economic surplus by year 3	3,974,038	4,124,622	3.79%
Banana	Total economic surplus by year 3	950,391.8	1,108,201	16.61%
Ground nut	Total economic surplus by year 3	49,860.52	98,365.93	97.28%
PLNT	Total economic surplus by year 3	171.72	1,349.96	686.15%

Table 6: Effect of decreasing the price of lime by 20% on total economic surplus in Central Region

	Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Total economic surplus by year 3[62]	1.02million	1.07 million	4.5%

Table 7: Effect on economic surplus by decreasing the price of lime for potato, and sweet potato

		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Potato	Total economic surplus by year 3	1,007,544	1,051,239	4.34%
Sweet potato	Total economic surplus by year 3	15,950.43	18,315.36	14.83%

[61] Considering the residual effect of lime application_ 50% of year 1-value in Year 2 and 25% of year 1-value in Year 3

[62] Considering the residual effect of lime application_ 50% of year 1-value in Year 2 and 25% of year 1-value in Year 3

V. What it will take to achieve the economic opportunity

To unlock the opportunities in the target markets, challenges need to be addressed across demand, supply, and enabling ecosystems to scale the adoption of lime.

Demand side interventions

Demand for lime is driven by a core set of interconnected factors**,** including high lime prices attributed to high distributions cost and lack of awareness on the timing, quantity, application method, and yield response times of lime. Some proposed key interventions to address these challenges can help unlock demand for lime and, in turn, solve for the supply side challenges.

Provide subsidies to reduce the price of lime to stimulate adoption of lime. The key barrier to the adoption of lime in the Western region is the high cost of lime. Subsides provided by the national governments can help to reduce the end user cost of lime and thereby increase uptake. The effectiveness of subsidies in driving up demand is dependent on where the subsidy is issued as detailed below.

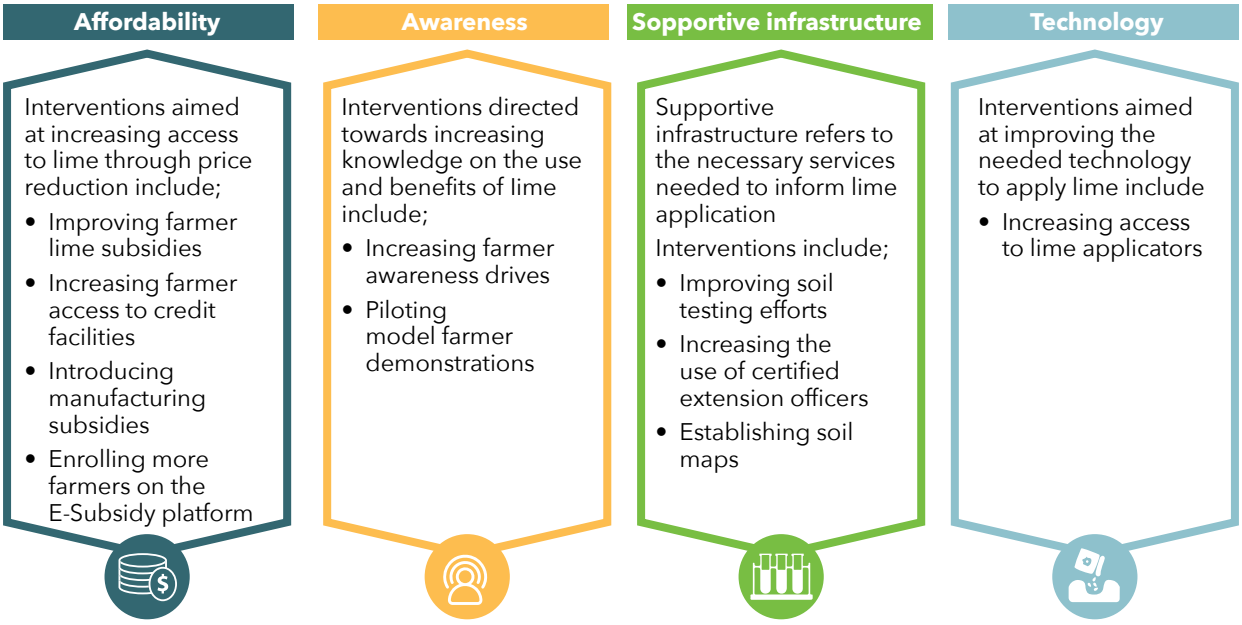

Figure 7: Summary of demand side interventions

Type of subsidy	Description
Farmer subsidy	• Increase lime subsidies provided in the E-voucher subsidy program under the National Value Chain Support Program. While the program provides subsidies of USD 50, only USD 16 can be used to purchase lime. This limits the amount of lime purchased. Increasing the lime subsidy can help stimulate uptake. • Increase registration of farmers for the E-voucher subsidy program. Currently, the key challenges for implementing the subsidy program include the low number of farmers currently registered limiting the effectiveness of the subsidy. • Work with social enterprises such as One Acre Fund to subsidize the cost of their agricultural packages, that include lime, in the region. The subsidies can be performance based pegged on increased agricultural productivity.
Manufacturers subsidy	• Provide incentives to manufacturers to lower the prices of lime. They include direct payments to manufacturers to reduce factory gate prices, tax exemptions for lime production machinery, and VAT exemption for lime products. However, there is a risk that subsidies may not trickle down to the farmer as other market actors in the distribution chain add higher markups.

Increase lime awareness drives and farmer demonstrations in target clusters in Western and Central regions. Prioritizing farmer education programs to raise awareness on the use and benefits of lime is critical. Working with the private sector will be key as lime manufacturers have the knowledge on the use of their products and have existing technical capacity to carry out trainings. For example, Homa Lime has conducted numerous farmer demonstrations in Western counties in collaboration with agro dealers. These marketing drives can cost 100,000 USD annually and mainly lie with lime producers.[63] As lime in the Central region is accessed through agro-dealers, lime manufacturers can liaise with them to provide farm demonstrations.[64] The government can complement the efforts by the private sector by upskilling extension officers on the use and benefits of lime that can be passed on to farmers. The awareness drives can be focused on:

Awareness drives topics	Description
Best practices on using lime	• Educates farmers on the timing of lime application to be at least one to two months before planting; quantity of application based on soil test and crop to be planted; application method based on lime spreading and mechanization; and measuring yield response to lime over time to accurately predict and raise awareness of the benefits of lime
Benefits of lime	• Provides details on the benefits of lime application - lowers toxic levels of aluminum and manganese, increases soil microbial activity through decomposition, overcomes the potential for calcium deficiency, increases symbiotic nitrogen fixation in legumes, increases the availability of phosphorus and other nutrients, and improves water retention in the soil

Increase soil testing efforts. The Bungoma, Busia, and Trans Nzoia County governments can work with development agencies to scale such efforts. A test of soil sample at a national laboratory goes for USD 15 and a farmer requires three sample tests from different points of the farm totaling up to USD 45,[65] which is 75% of the price of lime (per MT) in the counties. This renders testing unaffordable for farmers. Providing free test can help determine the specific areas that require lime. Similarly, providing complimentary services such as use of certified extension officers ensures that farmers have translated soil mapping results and information on ideal planting times and best farming practices and amounts of lime needed.[66] For example, the Kakamega County Government, in collaboration with AGRA during its Soil Health Programme 1, supported soil testing for the whole county which highlighted that soil acidity was a major problem. This spurred the county government to decide to introduce a fertilizer subsidy for blended fertilizers especially Mavuno.[67]

Establish national soil maps. The Agricultural Sector Transformation and Growth Strategy 2019 – 2029 (Kenya's ten-year nationwide sectoral document aiming at developing and transforming the agricultural sector) includes a national soil mapping initiative. This initiative is expected to identify and characterize all the soils nationally and develop matching soil suitability to the growth of specific crops while also identifying ways to improve the soils. The soil mapping initiative will provide compulsory lime vouchers for farmers with acidic soils and integrate mandatory partial use of the e-voucher for extension services to inform farmers of soil needs. The strategy also recommends mandatory procurement of lime for registered farmers who have acidic soils. The only drawback is that the lime quantities per farmer will be constant regardless of farm size. This is for ease of subsidy implementation.[68]

Provide mechanized lime applicators at an affordable cost to the farmers. Powdered lime is considered bulky, dusty, and cumbersome to handle and apply at the farm level. Mechanized lime applicators can reduce the labor and time spent on applying lime. The government can work with the private sector with firms like Hello Tractor to provide lime applicators at an affordable cost to farmers through subsidies. Cooperatives can also work with these firms to hire the lime applicators for their farmers before planting season to apply lime. Given that cooperatives can aggregate demand at the farm level, they can negotiate better prices for leasing/ renting the equipment.

[63] Ibid
[64] Ibid
[65] Ibid
[66] AGRA, Kenya Lime Policy Review, 2022
[67] Ibid
[68] Ibid

Supply side interventions

Efforts on the demand-side to increase the uptake of lime should be accompanied by efforts to improve the supply of lime at the required level of quality, quantity, and cost.

Utilizing existing production capacities will be key in lowering costs. In Kenya, current production capacities are underutilized. For example, Homa Lime uses 20% of its annual capacity.[69] Leveraging these capacities can enable manufacturers to gain greater economies of scale that could translate to lower factory gate prices for lime, stimulating greater uptake. Kenya also has sufficient limestone deposits in Kisumu, Kajiado, Nakuru, and Machakos to meet lime demand in the future. Mapping efforts are underway by the Ministry of Mining in the country to quantify the amount of limestone available.

Downward vertical integration can reduce costs. Manufacturers and distributors interact directly with farmers and can collect key data points such as name, location, and amount of lime purchased. This data can be used to project demand in future years and enable manufacturers to produce the exact quantities of lime demanded. Manufacturers can then leverage their existing distribution networks to sell and deliver lime directly to farmers with distributors paid on a commission basis, with no marketing expected. This would lower distribution costs as there would be no need for storage by the distributors/agro-dealers.

Aggregating demand at the farmer level through cooperatives and farmer unions can reduce the farmgate costs of lime. With larger volumes of lime, farmers can bargain for lower product prices and can demand lower distribution costs. Homa Lime noted that if the demand for lime increased 10 times, the production costs could be lowered by 10-15% with a similar decrease in distribution costs.[70]

Enroll more agro-dealers onto the E-voucher subsidy program. Currently, a limited number of agro-dealers are registered in the program.[71] Increasing registration of agro-dealers can increase the distribution nodes through which farmers can access lime.

Enabling environment interventions

Addressing gaps in finance and policy builds pathways towards commercial viability of lime. Interventions to improve access to finance and the policy environment and demand and supply side interventions are key to growing the lime sector.

Build the body of knowledge on lime in the Central region. Increasing the literature on crop yield response due to application of lime in Meru County can help prove the case for lime. This can be achieved by funding studies on lime application rates and crop yield responses in affected areas. Local universities in the county can work with national research institutions such as KALRO to build the body of work in the region.

Upstream solutions also need to be taken into consideration to limit the spread of acidic soils. This entails the promotion of non-acidifying fertilizers such as Single Super Phosphate (SSP), Calcium Ammonium Nitrogen (CAN), Nitrogen Phosphorous Potassium (NPK), and Mavuno

[69] Ibid
[70] Ibid
[71] Ibid

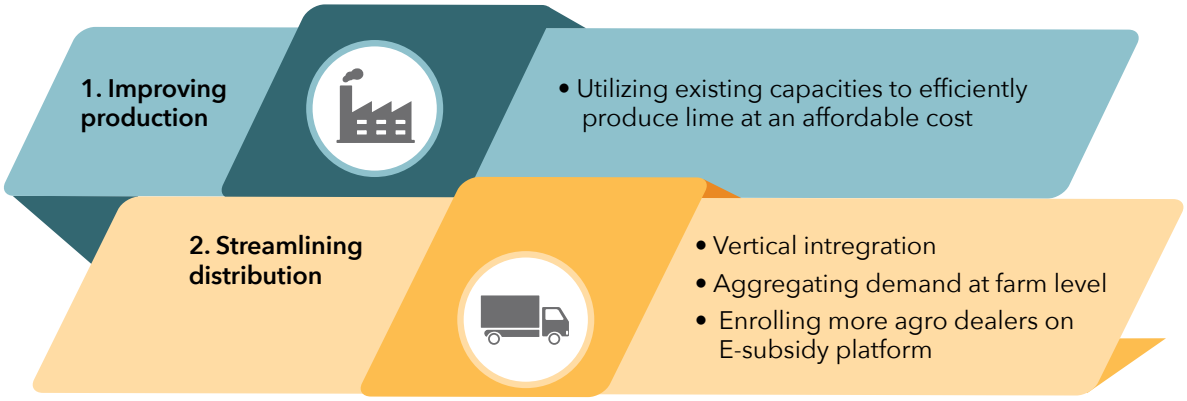

Figure 8: Proposed interventions to meet supply side challenges

Type of subsidy	Description
Creation of favorable lime policies and regulations	• Develop a guiding lime sector strategy to scale the adoption of lime and limit acidification of soils. This strategy would guide government effort that prioritize soil acidity as a critical issue. • Develop standards and quality guidelines for lime mining and manufacturing. The standard would govern the lime quality required. This should include clear labeling standards that detail the mineral specification such as the calcium carbonate content. • Create a harmonized lime guide that standardizes soil testing and results across different service providers and establishes best practice on the timing, quantity, application method, yield response, and articulates the benefits of lime. • Revise tax policies to create tax incentives for new and existing lime producers and distributors to reduce the final cost of lime and encourage local production of granulated lime
Provision of patient capital and mezzanine financing	• **For manufacturers and market intermediaries:** Partnerships between traditional banking institutions, NGO's and private investors to provide either guaranteed loans or mezzanine financing at cheaper rates would encourage more investment into storage facilities. Lower interest rates and grace periods would allow for demand uptake to increase slowly without considerable strain to settle interest obligations in the immediate term for storage or machinery investments. Further investment by NGO's or Government agencies into publicly available investment reports that project the profitability of lime would also encourage faster release of funds from banking institutions or foreign investors. • **For farmers:** Provide additional access to more patient capital that allows for long credit terms that match the effectiveness period of lime (1-3 years) and also have low interest rates for farmer payback is manageable over longer periods. This can be done through partnerships with the government financials agencies such as the Agricultural Finance Cooperation and the One Acre Fund. Their cooperation with farmer-based organizations can help increase community awareness as well as leverage social group networks to ensure high rates of repayment on any credit

(crop specific blended fertilizers). This can be achieved by working with fertilizer manufacturers and agro dealers to promote the use of non-acidifying fertilizers and drive awareness among farmers on the effects on acidifying fertilizers on their soils and crop yields. For example, in 2018, the National Government of Kenya drafted an ambitious programme that aimed to restrict farmers to purchase fertilizer that suits their soil in a bid to curb deteriorating soil health.[72] Such efforts can help curb the spread of soil acidity.

> *"We are currently working on a scheme that will see the government issue e-vouchers to farmers in the next planting season to ensure that they get only the fertilizer that suits soils at their local agro-vets,"*
>
> **- Hamadi Noga, Agricultural Principal Secretary**

Figure 9: Example of upstream Government efforts

[72] Ibid

VI. Who is required to achieve the economic opportunity

A successful implementation will require concrete solutions to be carried out by private sector actors, donors, and government.

The private sector can strengthen existing distribution for lime, strengthen research activities, and scale awareness of lime. Existing lime producers can collaborate with other agricultural input producers to leverage existing fertilizer distribution chains to distribute lime products. Lime producers can also work with local governments and farmer cooperatives to conduct awareness drive to increase the uptake of lime as they have the knowledge on and use of their products. The private sector can also help build the body of research by funding studies in lime and/or providing necessary lime materials to conduct lime trials by university researchers.

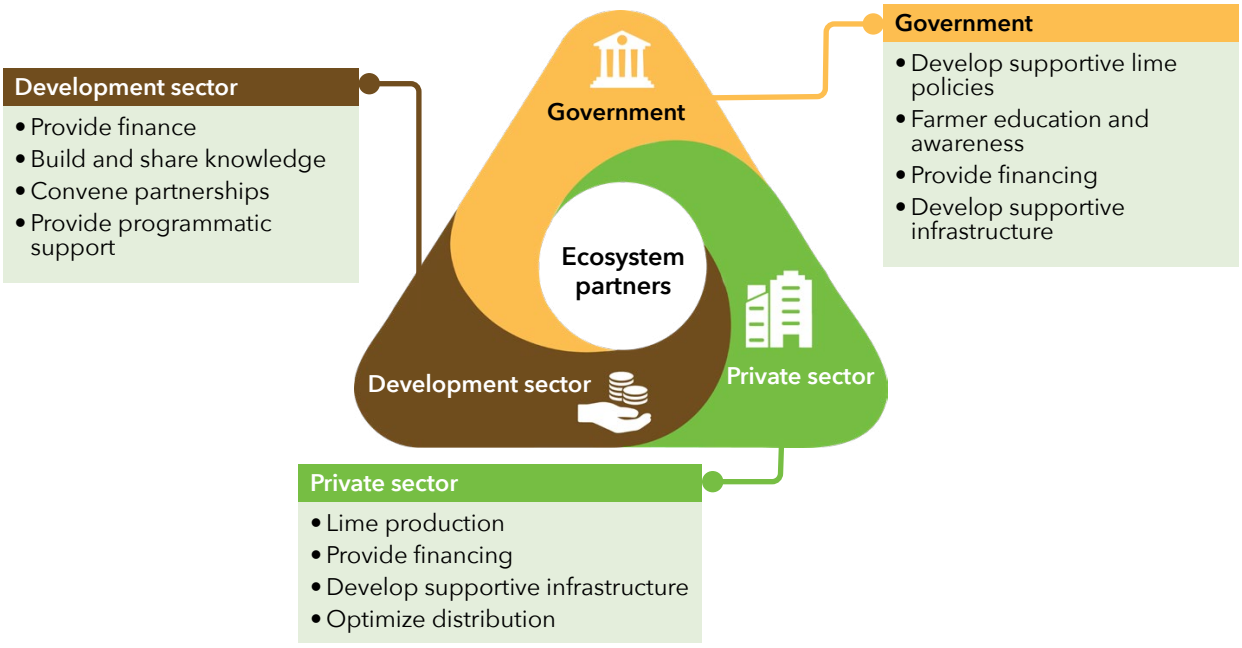

Figure 10: Role of ecosystem partners for successful implementation

Actor	Role
Lime manufacturers	• Work with county governments and development agencies to promote the use of lime through awareness drives and farmer demonstrations. The manufacturers can supply the lime that can be used for demonstrations and provide guidance on best application practices. • Collaborate with development agencies to pilot farmer trials by providing lime at no cost or subsidized prices to demonstrate the benefits of using lime. • Work with national research institutions such as KALRO to build the body of evidence on the use of lime by supporting lime trials across the country. The support can be in kind by providing the quantities of lime needed for the trials. • Work with the national government to promote the use of blended fertilizers. • Leverage existing fertilizer supply chains to distribute lime
Agro-dealers	• Distribute inputs through the input subsidy program to increase the supply of lime. The key incentive for agro-dealers would be increased sales provided the demand for lime is high. The involvement of agro-dealers is also expected to increase the demand for lime from manufacturers
Soil test providers	• Work with county governments to provide soil tests at a subsidized cost
Mechanized service providers	• Rent/lease lime applicators to governments and cooperatives at an affordable cost to aid lime application on farms

The development sector can create linkages among actors and fund/ support high impact and large-scale initiatives. Development partners such as AGRA have been pivotal in scaling lime trials and building the field of research in Western region. Funding research in other regions such as Meru County can help determine the impact of lime on crop yield that can build the case for lime. Development partners can support building and sharing information and knowledge on lime to contribute to the knowledge base of lime. This could be done through convening partnerships/ providing funding for more research and knowledge sharing.

A coordinated government effort that prioritizes soil acidity as a critical issue is key. The national and county government can create an enabling environment for the development and growth of the sector through developing supportive policies and regulations. Supportive policies for demand generation can be around lime use and application and support on the supply side can be around de-risking private sector investments in the supply chains through public-private partnerships, and guarantees, among other financial instruments. Moreover, developing supportive infrastructure such as soil testing labs can increase awareness on the issue of soil acidity. Examples of government partners that can be engaged include the Ministry of Agriculture, Livestock, and Fisheries, KALRO, and individual county governments.

Actor	Role
Non-governmental organizations	• Coordinate efforts with stakeholders to develop the draft agricultural lime manual. The stakeholders can include lime and fertilizer manufacturers, distributors, farmers, research institutions, ministry extension and policy staff (both national and county, universities and other NGOs working in the lime industry • Fund research studies and disseminate information to build the body of knowledge on lime benefits and use

Actor	Role
National government	• Develop a guiding lime sector strategy to scale the adoption of lime and limit acidification of soils. • Develop standards and quality guidelines for lime mining and manufacturing. • Create a harmonized lime guide that standardizes soil testing and results across different service providers and establishes best practice on the timing, quantity, application method, yield response times, and articulates the benefits of lime. • Avail more financing for lime products. Lime subsidies remain a key policy instrument that can be used by Kenyan Government to boost productivity of smallholders. Improve access to credit through co-operatives that help farmers to buy lime on credit and repay their costs over a relatively long period. • Promote the use of lime applicators in the Draft National Agricultural Mechanization Policy to increase awareness and use of lime technologies • Promote the use of non-acidifying fertilizers
County governments	• Conduct farmer awareness drive and campaigns in collaboration with other stakeholders • Improve soil testing capabilities by upskilling extension officers and providing/subsidizing soil testing services
National agricultural research Institutions e.g., KALRO	• Strengthen the evidence base for lime is important to increase the scientific case and increase buy-in from policy makers

VII. Conclusion and Next Steps

The study of lime and its effect on soil health in Kenya is still at its early stages, with the GAIA project seeking to enhance its contribution to healthier soils and land management towards smallholder enterprise development. This study supports GAIA's efforts by identifying high value target markets where lime can generate the most value for lime producers and farmers. **The insights provided in this report are still preliminary as the data used are at an early stage and continues to be refined by GAIA. More data refinement is needed before we can recommend large investments by the government and private sector actors. However, given a high level of confidence in the economic benefit in the identified markets, efforts on the supply and demand-side should begin to be implemented to build momentum and to validate success before the development of national investments in 18-24 months.**

As a first step, we recommend **piloting lime adoption activities** in the target markets to highlight the proof of concept to both farmers and government – ideally highlighting the benefits of lime. The pilot can be targeted in specific areas and can target certain farmers to prove the case. This will require specific monitoring and evaluation activities to assess the impact of lime use on crop yield and consequently farmer revenue over the years.

The data from M&E activities can also be used to **further research and refinement on crop yield response** to the application of lime in various regions. This can also be supplemented by independent research studies on the effects of lime on crops in various regions in Kenya to build a robust database. This will enable stakeholders to align and collaborate and develop the investment case in various regions. The learnt lessons from pilot regions also need to be translated into a report that can help refine and inform future lime interventions in other regions. The report can focus on i) lime adoption rates, ii) crop yield response, iii) economic benefit to farmers, and iv) implication of increased demand for producers in the region.

Finally, there is a need to **develop a national investment plan** in the next 18-24 months that would provide a detailed market sizing for lime, assess the supply and demand subsidies needed, provide timelines, and highlight the opportunity cost of investing in lime. This can then be presented and validated by key national stakeholders.

VIII. Annex

Literature review and stakeholder engagements

To support the development of this report, we conducted a literature review of the outputs from other work packages (noted below), conducted secondary research, and spoke with experts to test our assumptions and understand the likely impact of increased demand on production and distribution of lime.

Table 8: List of work packages and documents reviewed

Workpackage	Organization	Description
GAIA ex-ante analysis	CIMMYT	Characterizes the acidic soils in the focus countries
A Review of Agricultural Lime Policy in East Africa: A case of Ethiopia, Kenya, Rwanda, and Tanzania	AGRA	Studies the national policy environment related to agricultural lime in the four focus countries
Kenya Lime Value Chain Analysis and Report	KALRO and CIMMYT	Studies the agricultural lime value chain in Kenya

Table 9: List of stakeholders consulted

Name	Organization
Richard Stonewigg, CEO	Lachlan Kenya
Joseph Alubakar, General Manager	Homa Lime

Sources of Data

Table 10: List of data sources

Data	Source
GAIA ex ante analysis	CIMMYT
Economic surplus analysis for crops	CIMMYT
Crop Response to Lime based on exchangeable acidity	CIMMYT
Market prices for crops	CIMMYT
Number of farmers by crops in counties and target regions	KNBS, Kenya Population and Housing Census Report – Volume IV, 2019 (Table 2.21 and 2.22) *(To compute farmers per region, we assumed an equal spread of farmers per sq km across the county and distributed them proportionally to the total size of the region)*
Food production by county	Ministry of Agriculture, Kilimo data, Accessed May 2022
County sizes	Ministry of Devolution, Counties by Area, Accessed May 2022
GDP by county	KNBS, Counties by GDP, 2017

Table 11: Summary of some variables related to economic opportunities for lime in Western province and Central province for key crops.

	Western province	Central province
Average yield response to exchangeable acidity from liming (MT/ha)	0.99	0.06
Lime application per ha	1.07	0.05
Additional revenue within one year (USD) per ha	320.03	27.26
Additional revenue by the third year (USD) per ha	519.12	44.27
Economic surplus within one year (USD) per ha	213.03	22.26
Economic surplus by the third year (USD) per ha	345.92	36.14