Investment Case for Agricultural Lime in RWANDA

August 2023

CIMMYT | CGIAR

BILL & MELINDA GATES foundation

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I. Executive Summary

Lime is a viable solution to treat the highly acidic soils (59%) in Rwanda

Lime is a viable solution to treat soil acidity due to its impact on acid soils over a relatively short period of time, in-country short to medium term availability, and relative low cost (as a raw material). Soil acidity inhibits root growth and nutrient absorption, reducing yields of major cash crops (e.g.: coffee) and staple crops (e.g.: maize, rice, beans, and potatoes) in Rwanda. Reduced agricultural productivity threatens the food security of the country – with an estimated 18.7% of households classified as food insecure and 38.6% marginally secure[1] - and adversely impacts employment. While several solutions address soil acidity, including fertilizing residual materials, acid-tolerant seeds, and wood ash, lime is the most effective- studies[2] on Rwandan soil show that lime application on different crops to address soil acidity has led to significant improvement in crop yield.[3]

However, achieving significant uptake of lime is complex

Realizing significant uptake of lime is complex primarily due to several interrelated factors, including (i) the increase in yield resulting from application of lime is highly variable depending on the crop type, seed variety, starting soil composition, and general agronomic production factors; (ii) the full benefits of liming are distributed over multiple growing seasons; and (iii) limited data exists to calculate likely yield response across Africa. Consequently, there is limited proof of concept – leading to the current low uptake of lime.

Varying degrees of challenges in the demand, supply and the enabling environment further constrain the growth of the lime industry. In addition to limited proof of concept, limited awareness and knowledge of soil acidity management and cost factors further reduce demand for lime. On the supply side, high cost of lime is driven by capacity constraints, and sub-scale and inefficient distribution (poor infrastructure including transport and storage). Lack of demand means that the supply side is not incentivized to reduce costs and improve quality of lime.

It requires a lot of lime to treat farmland. While the amount of fertilizer and other inputs farmers often use are measured in kilograms per HA, lime is typically measured in tons per HA. This presents a particular challenge for African farmers, who often use non-motorized transport to deliver inputs to their agricultural plots.

Consequently, there is a need to first demonstrate the economic viability of lime

Given the complexity of the problem, it is important to identify nodes of entry that are likely to move the needle in terms of economic benefit to suppliers and farmers. There is a need to identify food basket crops and cash crops, aligned with the national agenda, that have the highest yield response to lime to evaluate the potential impact of lime on livelihoods and the economic surplus. Subsequently, understanding where, within the country, these economic surpluses exist, enables the selection of 'nodes of entry' where a farmer is likely to see the 'biggest bang for the buck' from lime application.

In Rwanda, the Eastern and Northern provinces possess 51% (700,000 ha) of the total cropland in the country, of which 26% is highly acidic (pH<5.5).[4] Moreover, these two regions produce 52% of the country's food and cash crops.[5] Moreover, while the Western and Southern provinces are the most acidic regions in the country and hence, have a significant potential need for lime (i) greater soil pH in Eastern and Northern provinces compared to Southern and Western provinces results in small lime requirements and hence lower total cost of lime; and (ii) high value crops in the Eastern and Northern provinces, for example, coffee (within the database of 26 crops analyzed in the ex-ante

1 World Food Programme, Rwanda - Comprehensive Food Security & Vulnerability Analysis, December 2018

2 Nduwumuremyi et al, Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2014

3 CIMMYT, crops yield response to lime application data, 2022

4 CIMMYT, GAIA ex-ante analysis

5 National Institute of Statistics Rwanda, Seasonal Agricultural Survey, 2021

analysis), result in higher economic surplus, even with small yield response to lime, based on the lower amount of lime required (and hence, lower total costs of lime). As a result, the Eastern and Northern provinces are ideal nodes of entry that can demonstrate the 'biggest bang for the buck' from lime application.

In the Eastern province, sweet potato, and potato have the highest potential economic surplus. Combined, these crops require 39,613.28 MT of lime to treat soil acidity with the potential to generate 11.82million USD additional revenue by the third year.[6] This translates into 5.39 million USD economic surplus, and a 3.96 million USD market for lime producers at a cost of lime of 100 USD/MT.[7] This level of economic surplus makes lime a commercially viable opportunity for these crops.

In the Northern province, potato, and sweet potato potentially produce the highest economic surplus as a result of using lime. Combined, these crops need 17,811.16 MT of lime to treat soil acidity and can in turn generate 6.74million USD additional revenue by the third year.[8] This translates into 3.85 million USD in economic surplus, and a 1.78 million USD market for lime producers at the current cost of lime of 100 USD/MT[9]. This level of economic surplus makes lime a commercially viable opportunity for these crops.

These crops are selected based on currently available yield response data from the ex-ante analysis 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 nationally important crops such as horticultural crops.

Achieving this economic surplus requires targeted investments to address demand and supply challenges

Realizing this economic surplus will require targeted investments to increase the uptake of lime and improve the commercial viability of supplying lime at the required level of quality and cost.

Scaling demand for lime will require conducting awareness campaigns focused on why lime is needed, how it is used, and corresponding benefits. Access to infrastructure such as demonstration plots, soil testing tools, and storage facilities closer to farmers can drive the increase in lime demand. The Eastern province is likely to require additional awareness efforts given that there is no documented use of lime, unlike the Northern province where lime is currently used in Rulindo, Gakenke and Burera districts.[10]

Improving the commercial viability of supplying lime at the required level of quality and cost will look different for the Eastern and Northern regions. In the Eastern province, for instance, there is a need to establish distribution centers closer to farmers given that the closest production plant is located in Musanze (~155km away).

For both regions, there is a need to earmark patient capital and innovative finance products to support suppliers in quality production and improving their distribution systems – including last-mile delivery, especially in the Eastern province. There is also a need to provide business support to processors in need to become investment ready. Investments to get to scale on the supply side could reduce costs, hence creating additional economic surplus in the selected regions and beyond.

There is an urgent and critical need to strengthen the base of evidence in terms of different crop yield responses to lime and the impact of various factors (such as levels of pH and soil conditions) on yield response, before large investments are made in the sector. The yield response data used to develop this analysis are still in their early stages and are being refined, making it difficult to make conclusive recommendations. Hence, it is critical to refine these data before large investments are made in the lime sector. Additionally, comparing lime to other potential interventions to improve crop yields and farmer livelihoods is essential to select the most appropriate course of action.

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

7 CIMMYT data, 2022

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

9 Ibid

10 **Note:** In addition to the listed districts in the Northern province, lime is also used in the Western province (in Nyamasheke, Rusizi, Karongi, Rutsiro, and Ngororero districts) and in the Southern province (in Nyaruguru, Nyamagabe, Nyanza, and Gisagara districts). **Source:** RAB, Guiding Acid Soil Management Investments in Africa (GAIA) Project, Agricultural Lime Value Chain Analysis in Rwanda, 2022

II. Defining the Challenge

In Rwanda, agriculture accounts for 24% of GDP and provides a livelihood to 70% of the country's labor force. The government of Rwanda (GoR)'s strategy for the agriculture sector aims to boost productivity and modernize and shift the sector from subsistence to a knowledge-based value creating sector. Key enablers include (i) promoting research and innovation; (ii) increasing the average productivity of key crops; and (iii) scaling the production of high-value crops. The additional value created in the sector will ultimately lead to increased economic opportunity, improved food security, and increased resilience- therefore boosting the country's economy and livelihoods of farmers.

However, current levels of soil acidity threaten the desired sector growth and transformation agenda, with over 40% of Rwanda's arable land affected by soil acidity, of which 59% is identified as highly acidic, with less than pH 5.5. Most arable land affected by soil acidity is concentrated in the Western, Southern, and Northern provinces of the country. These regions are also some of Rwanda's most populous and agriculture production areas. Soil acidity inhibits root growth and nutrient absorption, reducing yields of major cash crops (e.g.: coffee) and staple crops (e.g.: maize, rice, beans, and potatoes) in the country. Reduced agricultural productivity threatens the food security of the country – with an estimated 18.7% of households classified as food insecure and 38.6% marginally secure[11] - and adversely impacts employment.

Lime is a viable solution to treat soil acidity due to its impact on acidic soils over a relatively short period of time, in-country short to medium term availability, and relative low cost (as a raw material). While several solutions address soil acidity, including fertilizing residual materials, acid-tolerant seeds, and wood ash, lime is the most effective. Studies[12] on Rwandan soil show that lime application on different crops to address soil acidity can lead to significant improvement in crop yield.[13] In Rwanda, two types of lime are available, Grade I lime produced from processing factories and Grade II lime which is artisanal produced. However, the government is promoting the use of Grade I lime due to its efficiency related to its fineness, higher purity and lower moisture content compared to Grade II lime as seen in the table below.

Table 1:Difference between Grade I and Grade II lime characteristics[14]

Characteristics	Grade I	Grade II
Calcium Carbonate Equivalent (CCE), %, min	70	50
Active lime (total available as CaCO3 + MgCO3), %, min	50	40
Magnesium (as MgO) %, max	10	10
Sieve size (mm)	0.25	2
Moisture content, %, max	10	12

However, realizing significant uptake of lime is complex primarily due to several interrelated factors, the increase in yield resulting from application of lime is highly variable depending on the crop type, seed variety, starting soil composition, and general agronomic production factors (and in many cases no benefit can be observed); (ii) The full benefits of liming are distributed over multiple growing seasons; and (iii) limited data exists to calculate likely yield response across Africa. Consequently, there is limited proof of concept – leading to the current low uptake of lime.

Challenges across demand, supply, and the enabling environment further constrain the growth of the lime industry in Rwanda. Demand is minimal due to low awareness, and high cost of lime and addressing them will be a prerequisite to unlocking growth of the sector. On the supply side, processors have technical and infrastructure challenges. Moreover, production capacity is currently underutilized due to low demand. There are also financing gaps across the value chain ranging from lack of investment in processing equipment to farmer's lack of access to finance for agriculture inputs. Figure 1 below shows a summary of the constraints in a three-tier framework.

[11] World Food Programme, Rwanda - Comprehensive Food Security & Vulnerability Analysis, December 2018

[12] Nduwumuremyi et al, Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2014

[13] CIMMYT, crops yield response to lime application data, 2022

[14] Rwanda Standard Board, 2021 as reference in RAB, Guiding Acid Soil Management Investments in Africa (GAIA) Project, Agricultural Lime Value Chain Analysis in Rwanda, 2022

Binding constraints	Rationale

Demand 	• **Demand remains minimal** due to various challenges and thus, the market is public-driven
	  • Cost is driven by high excavation and processing unit costs, transportation - for processors and hidden transportation costs for farmers
	  • Farmers may also have misgivings around yield improvements due to low quality and information asymmetry, and cash flow constraints which further limit demand

Supply 	• Lime producers **currently lack the capacity** and are unwilling to further invest due to low demand • **High transportation costs** as a result of diseconomies of scale and poor road infrastructure, either increase end price (demand) or limit economic viability of the supply chain • **Concerns around depletion of limestone in deposits** across the country in the short-term. However, there is no reliable knowledge on lime deposits or forward-looking discourse around complementing local supply
Enabling environment 	• Although the regulatory framework is largely supportive, some **policies and regulations are misaligned with on-ground realities**. For instance, the new processing requirements are unlikely to be fully met by small-scale processors in a short period of time • There are **financing gaps across the value chain** ranging from investments in processing equipment to farmers' financing or at least flexible payment schedules

Figure 1: Summary of binding constraints across the demand, supply, and enabling environment framework

On the demand side, although the use of lime has increased over time it remains minimal due to high farmgate cost, limited proof of concept, poor lime quality, and lack of awareness. The government of Rwanda, mainly through the Ministry of Agriculture and Animal Resources (MINAGRI) and the Rwanda Agriculture and Animal Resources Board (RAB) and development partners including One Acre Fund (OAF), Cultivating New Frontiers in Agriculture (CNFA), and Agribusiness Focus Partnership Organization (AGRIFOP) have put in efforts to increase uptake of lime by farmers through the provision of government subsidies on lime through the smart Nkunganire subsidy system in selected regions of the country, setting up demonstration plots, and training farmers on lime use. However, these efforts have been deficient due to the subsidy program only targeting 7 districts out of the 26 affected districts in the country, lime awareness being mainly limited only to demonstration areas, and poor lime quality being largely used due to its low cost compared to Grade I lime – although the new lime subsidy model is promoting the use of Grade I lime, Grade II lime (which is of poorer quality compared to Grade I lime) is 29% less expensive that Grade I lime.[15] This can lead to farmers using Grade II lime instead of Grade I lime, especially in districts that do not receive the 50% government subsidy. Moreover, limited information available on the appropriate lime application techniques, lime reaction time –which varies between 6 months to two years depending on the quality of lime used, level of acidity, soil of composition, and the type of crops the farmers produce, among others – further limits the uptake of lime.

Limited demand coupled with supply chain inefficiencies at the extraction, processing, and distribution stages results in high prices for lime. Processors/lime producers currently lack adequate capacity to enhance the quality of lime, and low demand results in an unwillingness to further invest in improved processor capabilities. Low capacity negatively impacts the physical quality of lime, reducing its effectiveness to achieve improved crop yield, thereby further limiting demand. Second, high transportation costs arise due to diseconomies of scale and inadequate / poor quality infrastructure. To put this in perspective, while the factory gate cost of lime currently stands at 77USD/MT, the farmgate cost of lime is around 114-124 USD/MT.

[15] RAB, Guiding Acid Soil Management Investments in Africa (GAIA) Project, Agricultural Lime Value Chain Analysis in Rwanda, 2022

Estimated cost breakdown
USD per tonne of Grade 1 Lime

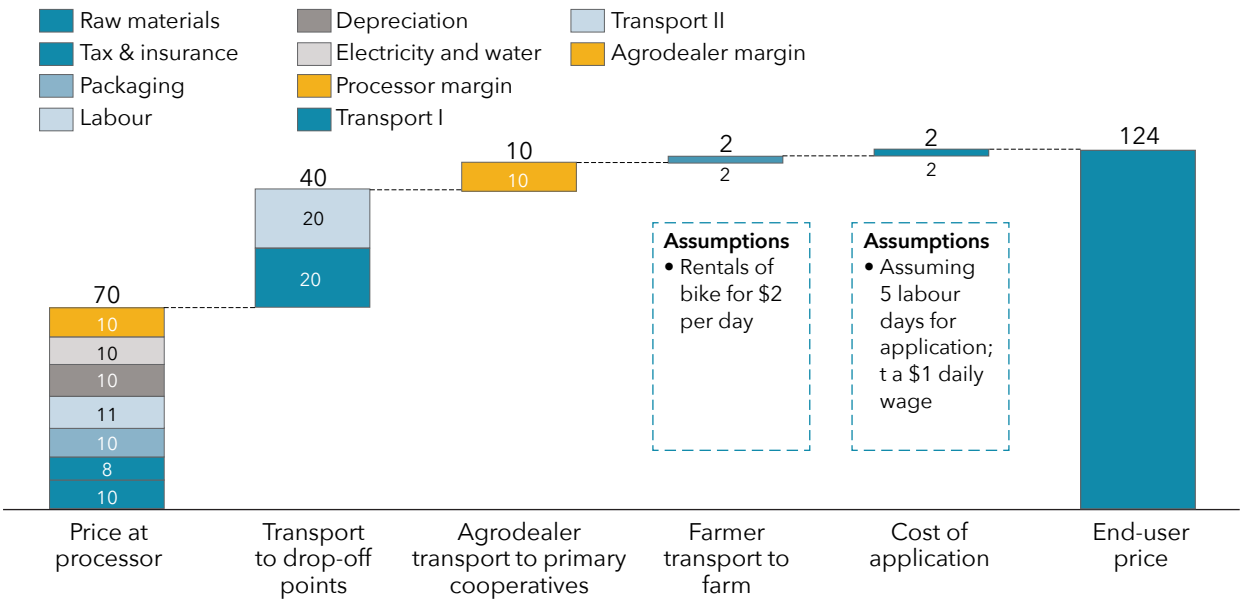


Figure 2: Cost breakdown of lime from production to end consumer[16]

Moreover, there are concerns on mid to long-term depletion of limestone. Estimates show that Rwanda has limestone deposits to last the soil acidity solutions for ~16 years.[17] However, there is limited reliable knowledge on lime deposits – whether new limestone deposits exist or the amount/quality of lime in existing deposits. In addition, there is hardly any forward-looking discourse on pathways to complement local supply. This large web of dependencies creates uncertainties amongst already resource constrained farmers.

In addition, there are financing gaps across the value chain. Financing gaps ranging from investments in processing equipment to farmers' financing remain a barrier to further investment in lime. Access to capital from traditional financial institutions remains limited due to a range of factors including: (i) high cost of capital that typically exceeds 17% interest rates which minimizes processors' borrowing appetite, (ii) limited investment-readiness of small scale processors – in regards to their professionalism in financial records, board and leadership, and (iii) limited and uncertain demand rendering it difficult for processors to secure sustainable off taker markets which further complicates financial institutions' job to project revenues that allow the processor to service financing obligations. For instance, although lime suppliers sometimes get contracts from public institutions and other organizations to supply lime to a specific region, interviews indicated no existence of long-term contracts with processors themselves.[18] On the farmer side, although larger and medium-size farms and farmer cooperatives with buyer arrangements may be more willing and able to pay for lime, independent smallholder farmers representing the largest share have cash flow constraints and generally rely on flexible payment schedules, e.g., payment after harvest. In the new distribution model, farmers are now expected to pay their contribution – 50% - to suppliers before accessing lime to ensure that their contributions are collected successfully and repatriated to government accounts.[19] Therefore, the lack of financing options tailored to smallholder farmers' realities further limits the purchase of lime.

[16] Dalberg analysis; RAB, Rwanda lime value chain analysis report, 2022
[17] Dalberg analysis; Nduwumuremyi et al (RAB), Mapping of limestone deposits in Rwanda and determination of quality of locally available limestone in Rwanda, 2017
[18] AGRA, Rwanda lime value chain analysis report, 2022
[19] RAB/MINAGRI workshops on lime distribution model, 16th July 2021

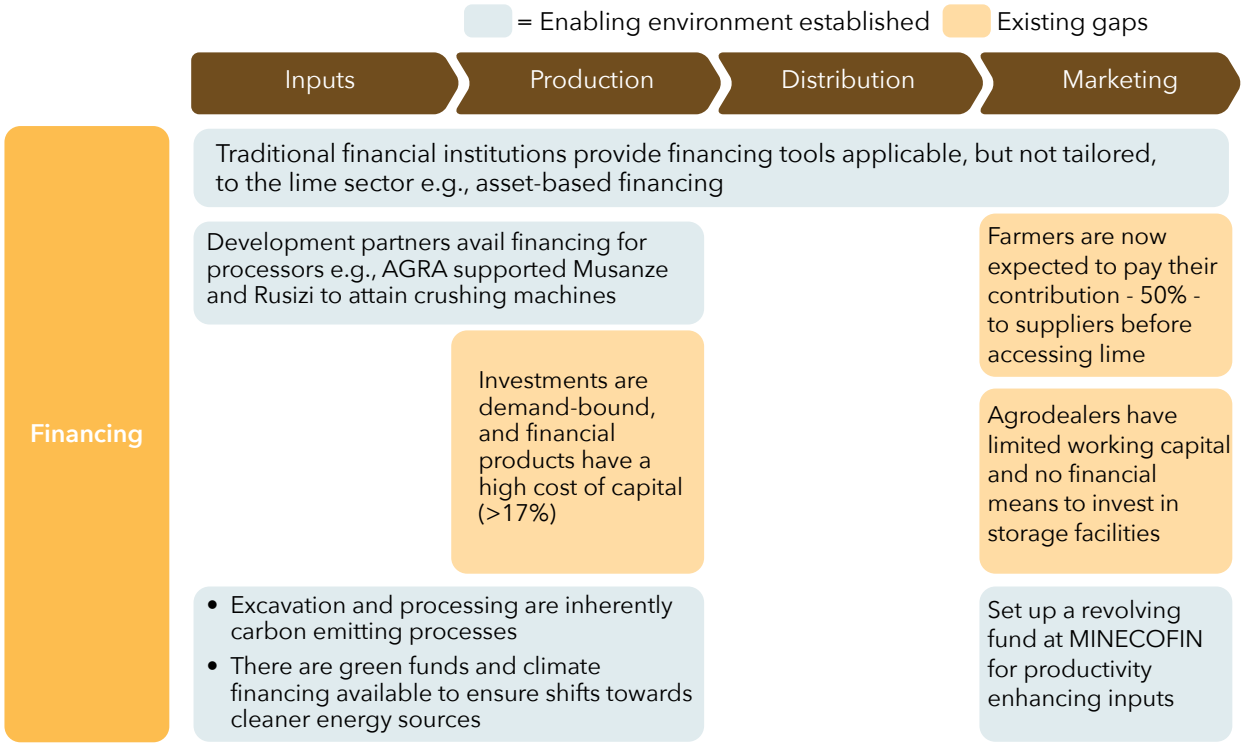


Figure 3: Synthesis of the financing enabling environment

Moreover, the newly established regulations around processing requirements further impede the growth of the lime industry. Stringent regulations on new processing requirements will only exacerbate processors' need for financing. New regulations stipulate the need for 10,000MT storage and packaging, a far cry from processors' actual capabilities in Rwanda.

Consequently, to find the "right intervention point", solutions need to address challenges across the lime value chain, particularly around demand creation, starting with target regions and crops. There is a need to focus interventions on target markets- highly acidic regions with crops with tested positive responses to lime resulting in an economic surplus in order to start building the economic case of lime to famers. These interventions should emphasize the how along the 'why' in awareness and demonstration efforts. In parallel, the supply side actors can explore options for improving the efficiency of quality lime production at scale to meet potential demand and leveraging innovative financing to make the necessary improvements. Moreover, leveraging supply routes, vertical integration, and technology can help establish efficient distribution. Complementary enabling environment interventions to facilitate the achievement of the supply and demand-side interventions are also critical to the growth of the lime sector.

III. Identifying the nodes of entry

Our approach to building an investment case for lime is anchored on identifying 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 due to 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 4.

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 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 5, the economic surplus calculates the return on investment for a farmer (per MT) due to the application of lime by considering yield increase 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, kind and amount of clay, and cropping and management systems used. To account 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 nationally important crops such as horticultural crops (e.g.: French beans, snow peas, avocado, etc.).

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

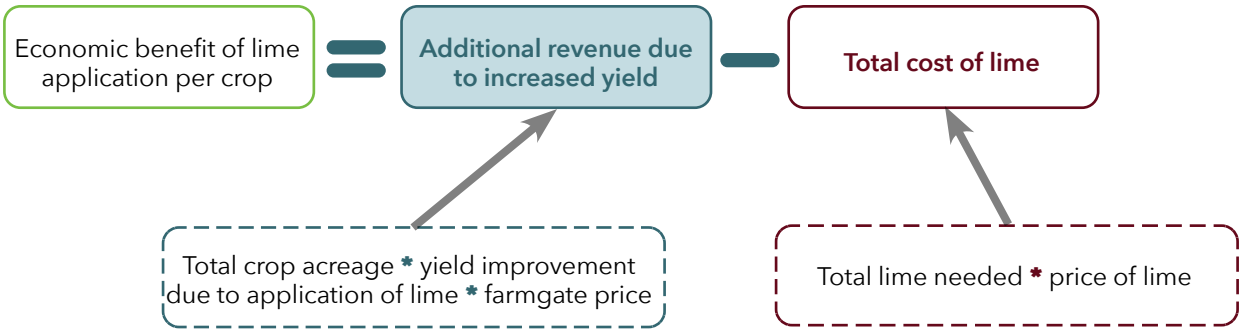
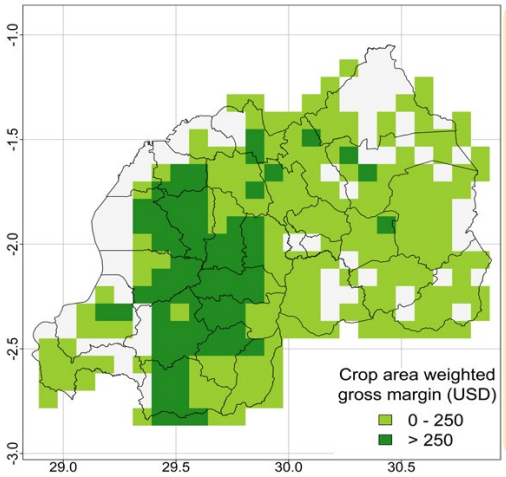


Figure 4: Economic Surplus Formula



Eastern province

Districts:

- **Rwamagana, Gatsibo, Nyagatare, Ngoma, and Kirehe**

Key crops:

- **Sweet potato, and potato**

Northern province

Districts:

- **Gicumbi, Musanze, and Gakenke**

Key crops:

- **Potato, sweet potato**

Figure 5: Highest economic value areas in Rwanda

returns because soils need to get to 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.

IV. Economic Opportunity of Lime in Rwanda

The Eastern and Northern provinces of Rwanda provide the greatest economic opportunity to increase farmer productivity and revenues through acidic soil remediation. While the Western and Southern provinces are the most acidic regions in the country and hence, have a significant potential need for lime (i) greater soil pH in Eastern and Northern provinces compared to Southern and Western provinces results in small lime requirements and hence lower total cost of lime; and (ii) high value crops in the Eastern and Northern provinces, for example, coffee (within the database of 26 crops analyzed in the ex-ante analysis), result in higher economic surplus, even with small yield response to lime, based on the lower amount of lime required (and hence, lower total costs of lime) As a result, the Eastern and Northern provinces are ideal nodes of entry that can demonstrate the 'biggest bang for the buck' from lime application.

Key districts in these provinces with particularly high economic surplus are Rwamagana, Gatsibo, Nyagatare, Ngoma, and Kirehe in the Eastern province and Gicumbi, Musanze, and Gakenke in the Northern province. A series of conditions that make these regions feasible starting points for lime investments are detailed in the subsequent paragraphs. Key crops with the highest economic surplus are sweet potato, and potato in the Eastern province and potato, and sweet potato in the Northern province.

Table 2: Summary of economic opportunities for lime in the Eastern and Northern provinces

	Eastern province	Northern province
Total market size for lime (Mt)	39,613.28	17,811.16
Total market size for lime producers (USD)[20]	3.96 million	1.78 million
Total economic surplus (USD)[21]	5.39million	3.85 million

Opportunities in the Eastern province

The Eastern province possesses 37% (510 thousand ha) of the total cropland in the country, of which 98% is acidic (pH<6.5) and accounts for the production of 35% of the country's food and cash crops. Of the seven districts that make up the Eastern province, Nyagatare, Gatsibo, Rwamagana, Ngoma, and Kirehe are of concern due to their acidic soils and associated positive economic returns due to lime application. On average, 88% of the cropland in this region has a pH between 5.5 and 6.0 and 4% of the cropland has a pH less than 5.5. This region is the furthest from lime deposits and lime processors who are mainly located in Musanze District in the Northern province and in Karongi and Rusizi districts in the Western province. The closest lime processors are located in Musanze, approximately 155 KM away.

An analysis of crops with highest economic surplus after lime application in the region highlights sweet potato, and potato as key crops of focus as they generate the highest economic returns.

Combined, these crops require 39,613.28 MT of lime to treat soil acidity in the first year and can in turn generate 11.82 million USD additional revenue by the third year. Assuming the price of lime to be 100USD/MT, this translates into an economic surplus of 3.32million USD within the first year and 5.39 million USD by the third year[3]. The high economic surplus can be attributed to the high price of these crops relative to the price of lime and the modest amounts of lime required reducing costs. The table below provides details about these crops assuming no residual effect due to lime application.

[20] Calculation assumes cost of lime is $100 USD/Mt

[21] CIMMYT, 2022; Note: calculations are based on the sum of the first three years of surplus.

[22] CIMMYT, 2022; total for the first 3 years - calculated using a 50% discount rate for the second year and a 25% discount rate for the third year

Table 3: Crops with the highest economic surplus in the Eastern province[23]

	Crops	
	Sweet potato	**Potato**
Current area under production (ha)	56,395.88	11,983.32
Yield increase from lime application (MT/ha)	0.35	0.31
Total demand for lime (MT)[24]	34,643.98	4,969.3
Market price (USD/MT)[25]	290.7	429.85
1st year total additional revenue (USD)	5,699,927	1,581,934
Total additional revenue by the third year (USD)	9,255,646	2,568,774
Current cost of lime at the farmgate (USD/MT)	100	100
Total cost of lime needed in the 1st year (USD)	3,464,398	496,930
Economic surplus within one year (USD)	2,235,529	1,085,004
Total economic surplus by the third year (USD)	3,630,093	1,761,850

Opportunities in the Northern province

In the Northern province, 84% of the cropland is highly acidic (pH<5.5) and the region accounts for the production of 15% of the country's food and cash crops. The Northern region is made up of five districts accounting for 14% (190 thousand ha) of the total cropland in the country, of which 84% is highly acidic (pH<5.5). Of the five districts, Gicumbi, Musanze, and Gakenke are of concern due to their acidic soils and associated positive economic surpluses due to lime application. This region is well placed in relation to the location of lime deposits and lime processors. For instance, there are five lime producers located in Musanze that source their lime from lime deposits in the same districts.

An analysis of crops with highest economic surplus after lime application in the region highlights potato, and sweet potato as key crops of focus as they generate the highest economic returns.

Combined, these crops need 17,811.16 MT of lime to treat soil acidity in the first year and can in turn generate 6.74 million USD additional revenue by the third year. Assuming the price of lime to be 100USD/MT, this translates into an economic surplus of ~2.37million within the first year and ~3.85 million USD by the third year.[26] The high economic surplus can be attributed to the high price of these crops relative to the price of lime and the modest amounts of lime required reducing costs. The table below provide details about these crops assuming no residual effect due to lime application.

Table 4: Crops with the highest economic surplus in the Northern province[27]

	Crops	
	Potato	**Sweet potato**
Current area under production (ha)	31,620.96	3,606.69
Yield increase from lime application (MT/ha)	0.27	0.51
Total demand for lime (MT)[28]	15,695.68	2,115.48
Market price (USD/MT)[29]	429.85	290.7
1st year total additional revenue (USD)	3,618,361	530,460.6
Total additional revenue by the third year (USD)	5,875,562	861,371.8
Current cost of lime at the farmgate (USD/MT)	100	100
Total cost of lime needed in the 1st year (USD)	1,569,568	211,548
Economic surplus within one year (USD)	2,048,793	318,912.6
Total economic surplus by the third year (USD)	3,326,868	517,856.3

[23] This analysis uses ex-ante analysis data on yield response to exchangeable acidity
[24] Based on the ex-ante analysis on lime needed
[25] Selina Wamucii, Agricultural Commodity Prices
[26] CIMMYT, 2022; total for the first 3 years - calculated using a 50% discount rate for the second year and a 25% discount rate for the third year
[27] This analysis uses ex-ante analysis data on yield response to exchangeable acidity
[28] Based on the ex-ante analysis on lime needed
[29] Selina Wamucii, Agricultural Commodity Prices

Key Sensitivities

The overall economic surplus generated by lime application and its impact to farmers increase with a reduction in the price of lime. This impact will be different for different regions and crops.

Eastern Province

On average, a 20% decrease in the price of lime leads to an approximately 24% increase in the total economic surplus generated from liming of sweet potato, and potato in the Eastern province.

On crop-by-crop basis, a decrease in the cost of lime by 20% increases total economic surplus (by 3 year) from sweet potato, and potato by 30.99%, and 9.16%, respectively.

Northern Province

On average, a 20% decrease in the lime of price leads to a 15.05% increase in the total economic surplus generated from liming of potato, and sweet potato in the Northern province.

On a 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 15.32%, and 13.27%, respectively.

Lime profitability is largely driven by the crops market prices in relation to the cost of lime. Hence, interventions geared towards optimizing/ reducing the cost of lime will ultimately lead to an increase in the economic surplus generated, making lime even more commercially viable for more crops in these regions and beyond.

Table 5: Sensitivity analysis of the economic surplus due to liming in the Eastern province

	Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Total economic surplus by year 3[30]	5.39 million	6.68 million	23.86%

Table 6: Crop-by-crop sensitivity analysis of the economic surplus due to liming in the Eastern province

		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Sweet potato	Total economic surplus by year 3	3,630,093	4,755,204	30.99%
Potato	Total economic surplus by year 3	1,761,850	1,923,234	9.16%

Table 7: Sensitivity analysis of the economic surplus due to liming in the Northern province

	Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Total economic surplus by year 3[31]	3.85million	4.42million	15.05%

Table 8: Crop-by-crop sensitivity analysis of the economic surplus due to liming in the Northern province

		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Potato	Total economic surplus by year 3	3,326,868	3,836,607	15.32%
Sweet potato	Total economic surplus by year 3	517,856.3	586,559.4	13.27%

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

[31] Ibid

V. What it will take to achieve the economic opportunity of lime

In order to increase the uptake of lime and improve the commercial viability of supplying lime at the required level of quality and cost, a range of interventions across the lime value chain are key.

Demand-side interventions

To promote the uptake of lime, increasing farmers' awareness of lime, its benefits and how and when it is applied is critical. Interventions focused on farmers behavioral change will facilitate uptake. Behavioral change in farmers will necessitate efforts focused on showing farmers the results/benefits of lime use through demonstration plots and field visits to hear other farmers testimonials on the use of lime. This will be especially important in the Eastern province given that there is no documented use of lime in this region.[32] In the Northern province, lime is primarily used in select districts - Rulindo, Gakenke and Burera districts. However, there is a need to scale it to more districts including Gicumbi and Musanze given the potential economic surplus that can be generated by the use of lime in these districts for soil remediation. Moreover, given that more lime efforts have only been observed in some districts in the Southern and Western provinces of the country due to the high acidity of soils in these regions, it is key to learn from these when setting up demo plots in the Northern and Eastern provinces.

Different actors can create or increase awareness in these regions. For instance, existing farmer groups and agricultural marketing cooperatives can effectively reach their constituents. Moreover, given that farmers might be more likely to accept messaging on lime from the government and government channels as compared to the private sector, community leaders and trusted extension services providers are well placed to support improved awareness due to their frequent interactions with farmers. These actors require support to ensure that they are disseminating the right information including on including timing of application, application methods, and benefits tailored to the crops that farmers grow.

Efforts to increase the uptake of lime can also be strengthened by the participation of the private sector. Existing lime processors can also play a role in increasing the uptake of lime by partnering with the distributors to provide small quantities of lime for farmers to test and build an

Type of subsidy	Description
Increase the uptake of lime in the selected regions	• Invest in targeted awareness campaigns starting with regions where the economic surplus of using lime is evident • Establish proof of concept; for example, through model farmers - focused on the benefits and application/timing of lime • Enable efficient access to relevant infrastructure; for example, soil testing, application methods - this can involve collaboration with extension officers
Improve the commercial viability of supplying lime at the required level of quality and cost	• Earmark patient capital and leverage innovative financing mechanisms for supply chain actors • Provide patient capital that supports streamlined and cost-effective distribution channels, e.g.- processors vertically integrating and providing distribution services • Provide business support to processors to enable them to become investment-ready • Setup a new production facility closer to target regions to reduce transport and logisticscost and ease farmers' access to lime • Adopt a phased approach to achieving new processing requirements to ensure that it does not take a toll on producers, leading to an increase in cost of lime

Figure 6: Synthesis of demand and supply-side interventions in the lime sector in the Eastern and Northern provinces of Rwanda

[32] AGRA, Rwanda lime value chain analysis report, 2022

evidence base – SOPAV is currently doing this. Lime suppliers can partner with development financial institutions to offer experimental lime to farmers through input loan schemes for farmers, provided these schemes have low interest rates and longer payback terms to allow for resource-constrained farmers to invest in them.

Moreover, there is a need to revamp soil testing to ensure that farmers know the quality of their soil to determine the right application of lime. Although MINAGRI and RAB have already developed country soil maps detailing pH levels and mineral composition and farmer cooperatives also support their constituents with soil testing, availing soil testing kits to these farmer cooperatives on the Rwandan market can decentralize soil testing services. Soil testing kits can be imported from soil test manufacturers in countries such as the United States, at retail prices – excluding import costs - starting as low as $30.[33]

These efforts need to be accompanied by efforts to streamline distribution and reduce the final price of lime for farmers. Given that large amounts of lime are needed to revamp soil acidity compared to other amounts of inputs (such as fertilizers) that farmers are used to transporting, increasing uptake of lime should be done hand in hand with distribution interventions that make it easy for farmers to carry lime to their farms. The Yara distribution model is a good example of a distribution intervention, whereby retailers – also referred to super agents - close to the farmers are used to distribute inputs closer to the farmers. Agricultural marketing cooperatives can also be sensitized to aggregate lime demand from farmers they serve into bulk procurement to facilitate easy access to lime at a reasonable price. Given that there are no processing facilities in the Eastern province (with the closest production plant located in Musanze, ~155km away) establishing distribution centers closer to farmers will help ease distribution and access to farmers. This would reduce transport and logistics costs and allow for subsequent interventions focused on last-mile delivery to farmers to be implemented.

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. Starting with quantity, given that estimates show that Rwanda has limestone deposits to last the soil acidity solutions for ~16 years[34], efforts should be invested to complement local production with imports, by leveraging regional ample limestone. For instance, Tanzania has a lot of untapped lime deposits that can leveraged.[35] Moreover, DRC also has extensive lime deposits in North Kivu, including Kasugho, southwest of Lubero, and in Katana.[36]

Moreover, achieving sufficient supply to meet potential demand, requires engaging existing lime suppliers (given that they are operating at subpar capacity due to limited demand) and quarry owners (including cement producers) given that they already have operational experience and are moderately well versed in the sector challenges compared to new entrants. Cement producers have far-reaching distribution networks that can be leveraged for ag lime distribution. Moreover, as mentioned above, the Eastern could benefit from more distribution centers closer to demand areas.

Vertical integration of actors across the value chain should also be explored in efforts to reduce the distribution costs. This will allow to capture more value in the supply chain and reduce costs incurred in distribution.[37] These cost savings would be reinvested in improving last-mile delivery either by (i) agro-dealers who would take on additional transport from drop-off points to centers nearer to farmers; or (ii) with reduced prices, farmers could more easily afford to transport from further drop-off points.

Improving production quality requires access to innovative finance instruments. For example, access to patient equity investments or below rate investments to quarry owners and cement producers would allow these actors to invest in (i) processes geared towards improving the quality of agricultural lime and (ii) improving distribution systems.

[33] Dalberg, Rwanda lime sector analysis, stakeholder interviews, 2021

[34] Dalberg analysis; Nduwumuremyi et al (RAB), Mapping of limestone deposits in Rwanda and determination of quality of locally available limestone in Rwanda, 2017

[35] GAIA mid-term review and planning conference, country investment case presentations

[36] IFDC, Solving Agricultural Problems Related to Soil Acidity in Central Africa's Great Lakes Region, 2008

[37] Ibid

Given the potential economic surplus, traditional banks are well placed to offer tailored products. For example, mezzanine financing options for the lime sector such as concessional debt options for working capital, credit guarantees backed by a third-party to minimize due diligence hurdles, longer-term financing in response to the expected duration to build demand, and alternatives to fixed assets as collateral. Adequate financing in the sector will require capacity building of traditional banks and other financial institutions to develop expertise in agriculture finance allowing them to develop better tailored financial products.

Support to build capacity to absorb capital will also be key. To ensure that processors can qualify for these varying types of financing and able to absorb this capital and use it for the intendent purpose, they will require business support to become investment ready. The business support can include capacity building session on building up professionalism in leadership, financial records-keeping, and pitching to potential investors, to name a few.

Moreover, adopting a phased approach to achieving new processing requirements should be considered. New regulations stipulate the need for 10,000MT storage and packaging, a far cry from processors' actual capabilities in Rwanda. These stringent regulations on new processing requirements will only exacerbate processors' need for financing. Hence, phasing out the achievement of these requirements can lessen the burden for processors and hence minimizing the risk of a spike in lime prices.

In efforts to ensure that the cost of lime is not a burden to farmers processor subsidies could be explored. These subsidies can lessen the financial burden of purchasing lime for the farmer while ensuring that processors can still make their margins.

It is important to note interventions to support lime processors should be tailored to individual processors needs to ensure that these interventions have the intended impact.

In addition to increasing the quality and quantity of lime supplied, these interventions will reduce the price of lime due to scale and efficiency. This will in turn increase the places where liming creates economic surplus for farmers.

VI. Who is required to achieve the economic opportunity of lime and how?

Realizing the economic opportunities requires a combination of private sector, development actors and government, by leveraging their unique value addition and know-how.

Private sector

The private sector can strengthen existing production and distribution for Ag lime in the Northern province and pilot production and distribution in the Eastern province by providing finance, streamlining and optimizing distribution. Commercial banks, investment banks and other private financial institutions can provide finance to lime suppliers to scale production to meet lime demand in the Northern province and pilot new production capabilities in the Eastern province closer to farmers in this region. In the event that setting a new production plant in the Eastern province is not feasible as it is further away from known lime deposits, finance can be provided to agricultural market cooperatives/farmers to enable them to afford the increased price of lime. Support to lime producers can enable them to achieve production efficiency, develop supporting infrastructure such as storage closer to farmers, and invest in vertical integration to achieve costs savings.

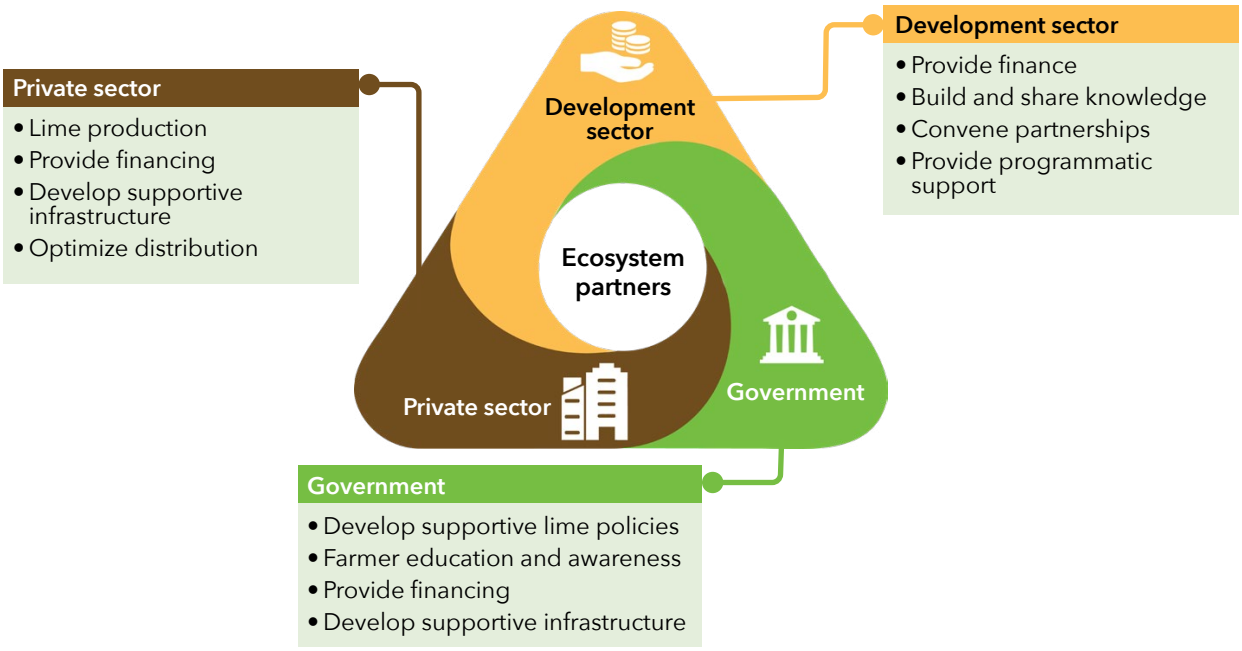


Figure 7: Role of ecosystem partners for successful implementation

Table 9: Examples of private sector actors that can be engaged

Intervention	Examples of private sector players
Lime production	• Existing ag lime producers such as ALICOMEC, COCOCHAUMA, Mashyuza Mashyuza Processing Company, and SOPAV • Cement producers such as CIMERWA
Provide finance	• Traditional commercial banks such as Bank of Kigali, I&M Bank, etc. • Private investors that could be attracted through the Kigali International Financial Center
Develop supportive infrastructure	• Existing ag lime producers such as ALICOMEC, COCOCHAUMA, Mashyuza Processing Company, and SOPAV
Optimize distribution	• YARA

Development sector

The development sector can create linkages among actors and fund/ support high impact and large-scale initiatives.

Development partners can support building and sharing information and knowledge on lime to ensure that all actors in the lime ecosystem are well versed on lime to inform their actions. This could be done through convening of different actors in the ecosystem including government, lime crushers, community leaders. This sector can also offer direct support to awareness efforts targeting farmers by coordinating with government actors on the ground.

Moreover, the development sector can provide support in building the evidence base for lime through more research. Scaling the uptake of lime in the selected regions and prioritized value chains and beyond in the longer term will require advocacy for the use of lime at a national level using the selected region and value chains as proof of concept. This will require support from the development partners to build the evidence base for lime through increasing scientific evidence on yield response to lime of various crops and variation in lime needed per ha based on various factors.

In addition, the development sector can support financing interventions led by the government and the private sector to jumpstart the lime sector. This could be through funding infrastructure development in partnership with the government or supporting lime processors either in terms of funding or capacity development to enable them to become investment ready.

Once (i) farmers in the Eastern and Northern provinces in the target value chains successfully adopt the use of lime at scale and (ii) increased efficient supply and competition lower prices of lime, hence increasing the economic value for lime use, the success story can be used as proof of concept to pilot and/or scale the use of lime in other regions in Rwanda affected by soil acidity. Once the residual effects of lime application materialize in the following years leading to significant increase in agricultural productivity, the knock-on effect on farmer livelihood improvement will be noted, acting as further testimony for farmers that are yet to adopt the use of lime.

Moreover, the development sector should explore alternatives to liming/identify other solutions to acidic soil management to limit the spread of acidity. This includes the promotion of non-acidifying fertilizers such as Single Super Phosphate (SSP), Calcium Ammonium Nitrogen (CAN), and Nitrogen Phosphorous Potassium (NPK). This can be achieved by working with fertilizer manufacturers in the country 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. In addition, wood ash and biochar can be extensively explored as solutions for managing soil acidity. This requires monitoring and evaluation efforts as well as piloting to accurately assess and document the impact of soil acidity management solutions before replicating these solutions to other acidic parts of the country. (Refer to annex table 2 for further analysis of solutions for managing soil acidity)

Government

The government can develop supportive policies and regulations that contribute to increasing awareness of lime and provide support necessary for the supply side. Although the enabling environment in Rwanda has been largely supportive of the lime sector, greater effort is required to develop concrete policies on lime use and application and lime deposit mapping. The government already provide lime subsidies to farmers mainly in the Western and Southern provinces of the country and there are set standards for other inputs' applications (including pests and fertilizers) set by RALIS and RSB to ensure food safety and agriculture productivity improvement outcomes; for instance, RSB provides training on the use of authorized and acceptable chemical inputs (fertilizers, pesticides) and their application.[38] However, similar standards for lime do not currently exist, and the guidelines on which different stakeholders agree, are not widely disseminated. AGRA plans to launch work, supported by technical assistants, which aims to establish standards around lime use, application, and distribution. These policies will readily complement awareness and demand driving initiatives at the farmer level and new quality standards and processor requirements

[38] RSB support towards food safety presentation by the National Certification Division, 2015

stipulated in the new distribution model. The goal is to fill the information and quality gaps that could have hindered improvements in yield after lime application at the farmer level.[39] Moreover, there is a need to ensure that current lime subsidies to farmers are targeting the identified high economic value areas given the proven economic surplus in these regions. This will in turn encourage the suppliers to target these regions, hence contributing to the realization of the benefits articulated in this report.

Government support on the supply side can also de risk private sector investments in the supply chains. This can be done through public-private partnerships, and guarantees, among others. Moreover, developing supportive infrastructure such as road networks to bring down distribution cost can contribute to the reduction in lime costs. Examples of government partners that can be engaged include the Ministry of Agriculture and Animal Resources (MINAGRI), Rwanda Agriculture and Animal Resources Development Board (RAB), Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA), Rwanda Standards Board (RSB), and the Ministry of Infrastructure (MININFRA).

To ensure the long-term sustainability of the lime solution to the soil acidity problem in Rwanda, the government should increase efforts to quantify the available lime deposits and seek more lime sources if needed. Given the uncertainties over Rwanda lime deposits and their lifespan – estimated to be about 16 years, government investments in understanding the lifespan of the lime deposits will help supply chain actors ensure their efficient use. Moreover, developing working relationships with other countries' lime sectors ecosystems, keeping in mind any cross-border trade and socio-political sensitivities is worth exploring to ensure the sustainability of the Rwandan lime sector. Tanzania and DRC can be considered, given abundance of lime deposits in these countries.

[39] Dalberg, Rwanda lime sector analysis, stakeholder interviews-NGO, 2021

VII. Conclusion and Next Steps

The insights provided in this report are still preliminary as the data used is 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.

The identified supply and demand interventions are tailored to the Eastern and Northern provinces to begin building the investment case for lime in Rwanda. Given that building the sector at a national level is complex, these regions and key crops selected can act as proof of concept for farmers and other relevant actors given that they show the economic benefits of agricultural liming through high economic surplus. This can encourage further investment in lime at a national level once proof of concept is established. In addition to encouraging more farmers to use lime, this will lead to cost reductions due to efficient distribution and encourage lime producers to scale production to meet demand and hence affecting cost curves as the sector matures. This requires monitoring and evaluation efforts to accurately assess and document the impact of lime in these regions before scaling to other parts of the country.

Given that the adequate uptake of lime largely depends on the ability to prove the actual benefit of lime on crop productivity and hence additional revenue, there is a need for continued research and refinement on crop yield response. The analysis in this study is limited to the 26 crop yield response data obtained from CIMMYT. This research and refinement should be focused on relevant crops grown in each region of the country and should take into consideration the varying levels of pH and soil conditions to build a robust database. Moreover, current land that could potentially be transformed into crop land necessitating lime should also be considered in the refinement of the data availed. CIMMYT/GAIA can collaborate with other relevant institutions to refine this data.

Once detailed data on crop yield response to lime per crop type and soil acidity is available, there is a need to develop a national investment plan in the next 18 to 24 months using this document as input to build a more detailed market sizing, more precise estimates of investments needed by the public, private and social sector (including assessment of supply and demand subsidies needed), and implementation timelines.

This investment plan should also provide insights on the comparison between lime and other upstream solutions to limit the spread of acidic soils. This comparison should focus on the cost for farmers, and effectiveness of the solution in the short and long term, among other factors. This will further unearth the best course of action that provides better returns to farmers while addressing crop yield and farmer livelihoods concerns.

These findings can then be presented and validated by key national stakeholders.

VIII. Annex 1: Work Packages and Document Reviewed and Stakeholders Consulted

To further support the development of this report, we conducted a literature review of the outputs from other work packages, 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 10: List of work packages and documents reviewed

Document	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
Rwanda Lime Value Chain Analysis and Report	RAB and CIMMYT	Studies the agricultural lime value chain in Tanzania
Seasonal Agricultural Survey	National Institute of Statistics Rwanda (NISR)	Provides data (including production volumes and average yields of key crops grown in Rwanda

Table 11: List of stakeholders consulted

Name	Organization
Twizere Pascal, Managing Director	SOPAV
Vedaste Uwimana, Managing Director	COCOCHAUMA
Pierre Celectin Habyarimana	Mashyuza Processing Company
Different stakeholders from various organizations who attended the GAIA convening on mid-term review and planning in Kigali in April 2022	

IX. Annex 2: Analysis of solutions for managing soil acidity

Factor	Fertilizing residual materials (FRMs)	Vermicompost	Acid tolerant seeds	Lime	Wood ash
Soil impact	Neutralizes soil acidity over time	Neutralizes soil acidity faster than conventional compost and chemical fertilizers	No neutralizing impact as soil continues to acidify without treatment	Neutralizes soil acidity over time	Neutralizes soil acidity quicker than lime
Availability	Not produced locally or regionally therefore limited access in country	Could be produced at large scale locally - Guder Lime Factor in the Oromia region already has a vermicompost production center	While some are readily available, such as, potato and wild oats, the type of triticale prevalent is an imported hybrid cross between wheat and oats	There are sufficient lime deposits in the country, however, lime is not sold by agro-dealers and easily accessible by farmers, particularly SHFs	Any burnt wood can be used as wood ash, but due to the large amounts needed and detrimental climate risks associated, it may not be readily available
Cost	High cost due to need for imports	Increased cost due to the need to mix with fertilizer	Relatively inexpensive if produced in-country	Lime is relatively inexpensive (cost of distribution results in high end user prices)	Wood ash is relatively inexpensive
Ability/Ease of use	Easier to use as it is in granulated form	Easy to use as it only requires following the furrow plowed with a line of application	Easy to use compared to soil acidity management methods	Lime in its powder form is difficult to apply to farms as it is easily blown away by wind and requires safety precautions	Wood ash is in powder form, making it difficult to apply to farms as it is easily blown away by wind and requires safety precautions
Climate impact	Relatively ecologically sustainable	Ecologically sustainable	May contribute to increasing acidity of the soil	Releases carbon dioxide in processing and also in its reactions with the soil once applied on the farm	Releases carbon dioxide in processing and also in its reactions with the soil once applied on the farm

From the farmer's perspective, indicates high difficulty/barriers, indicates medium, and little or not difficulty/barriers to implementation

Table 12; Summary of some variables related to economic opportunities for lime in Eastern and Northern provinces for key crops.

	Eastern province	Northern province
Average yield response to exchangeable acidity from liming (MT/ha)	0.34	0.29
Lime application per ha	0.58	0.51
Additional revenue within one year (USD) per ha	106.49	117.77
Additional revenue by the third year (USD) per ha	172.92	191.24
Economic surplus within one year (USD) per ha	48.56	67.21
Economic surplus by the third year (USD) per ha	78.85	109.14