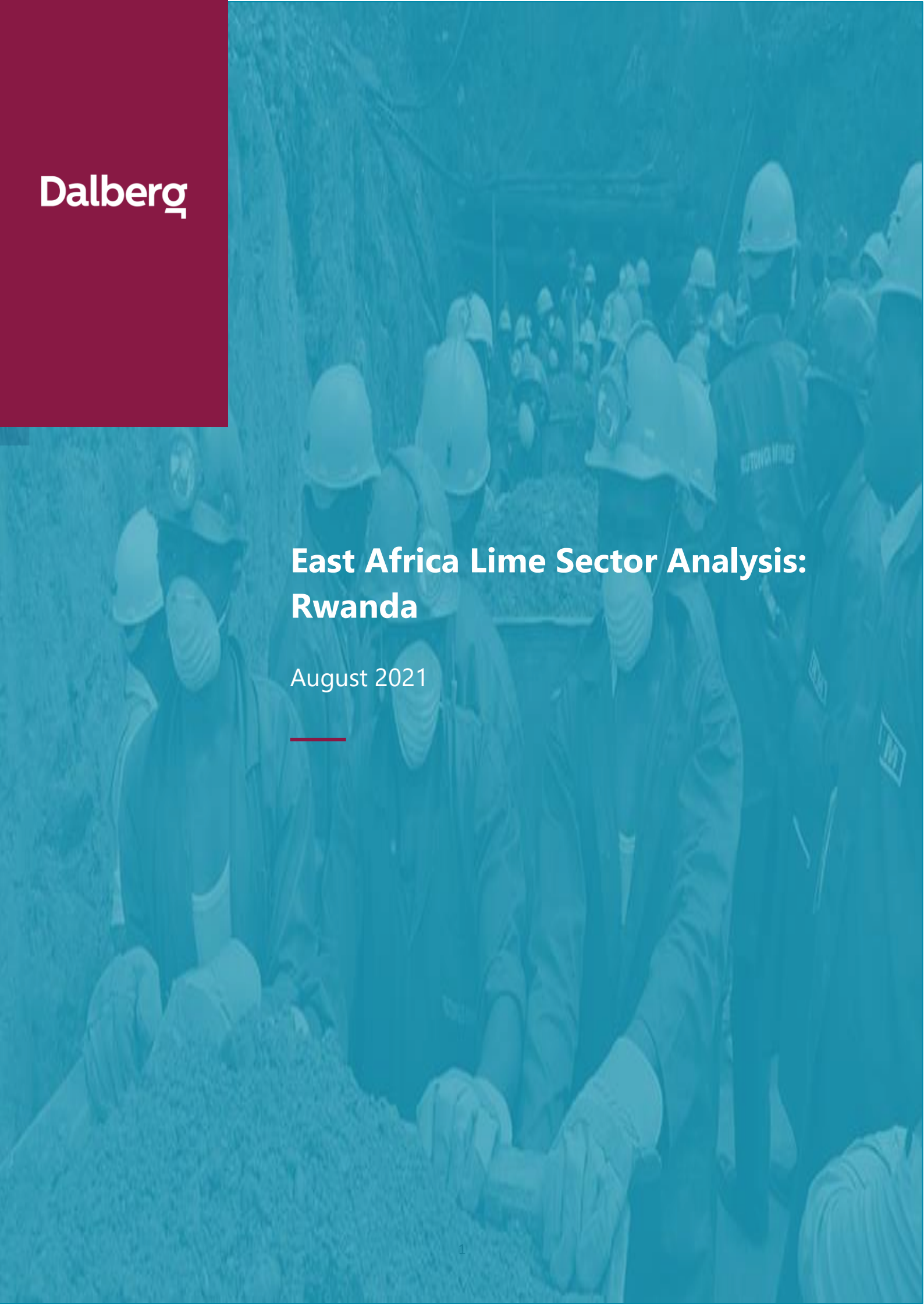


East Africa Lime Sector Analysis: Rwanda

August 2021

EXECUTIVE SUMMARY

Agriculture, a mainstay of the Rwandan economy, is threatened by widespread soil acidity. The agricultural sector employs ~70% of Rwandans, yet it contributed only 24% to the country's GDP in 2020.[1] The agriculture sector is one of the least productive sectors in Rwanda, and acidic soils exacerbate aggregate agriculture losses and low sectoral productivity. In a food system where nearly 57% of households are food insecure or marginally food secure[2], and where most of the farming households' harvest is for subsistence purposes[3], there is an urgent and critical need to address soil acidity to reduce yield losses and avail surplus for markets to boost Rwandan smallholder farmers' livelihoods.

Over 40% of arable land in Rwanda- 540 thousand hectares (Ha)- is affected by soil acidity.[4] 26 out of the 30 districts have challenges with soil acidity[5]– with some of the highest acidity levels (pH < 5.5) in the Northern, Southern and Western provinces, covering some of the country's most populous and agriculture production areas. Soil acidity reduces the biological activities of soil organisms and the efficiency of applied fertilizer.

Lime is an effective solution to address soil acidity in Rwanda. While several solutions address soil acidity, including fertilizing residual materials, acid-tolerant seeds, and wood ash, lime is the most effective due to its availability, effectiveness, soil impact, and cost from the perspective of a smallholder farmer. Studies on Rwandan soil show that lime application on different crops to address soil acidity has led to a significant improvement in crop yield- 63% in maize and up to 123% in beans.[6]

However, lack of demand is a critical binding constraint to effective lime application in Rwanda. In the past 3-4 years, the public sector, led by the Rwanda Agriculture Board (RAB) and the Ministry of Agriculture and Animal Resources (MINAGRI), alongside development actors, have pursued efforts to address soil acidity using lime. This has included classifying and distributing lime, as an agriculture input, within the national input subsidy scheme.[7] Despite these efforts, demand remains minimal. For instance, MINAGRI planned to distribute 50,924 tons of fertilizers and 15,211 lime to farmers during the 2021/2022 budget year[8]. Assuming the targeted 60kg/ha of fertilizer and the 2,500kg/ha of lime application, and an average landholding size of 0.3 ha rate, this implies that there were only 20,280 farmers applied lime compared to 2.8 million farmers applying fertilizer[9]. This suggests that application of lime is significantly less than fertilizer applications; yet, optimizing yield, requires addressing soil acidity as a precursor to ensuring effectiveness of fertilizer.

The key drivers of low demand are costs, long return on investment, poor lime quality, and misinformation. Costs are driven by high excavation, processing, and distribution costs – including the cost of last-mile delivery borne by farmers. Given that Rwanda already provides

[1] Statistica – Shares of Economic Sectors in Rwanda, 2020
[2] World Food Programme, Rwanda - Comprehensive Food Security & Vulnerability Analysis, December 2018
[3] NISR, Seasonal Agriculture Survey, 2019
[4] Stakeholder interviews (Government), 2021; Ruganzu, Improving crop productivity through wide scale promotion of lime and other ISFM technologies in the acidic soils of Rwanda, 2013
[5] Ibid.
[6] Nduwumuremyi et al, Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2014
[7] Stakeholder interviews (Government)
[8] The New Times, Farmers worried as fertilizer prices rise, 2021
[9] Dalberg analysis

subsidies, growth opportunities are highly dependent on demonstrating and communicating the value for money of lime application. For example, based on high level break-even analysis, 7%, 33%, and 35% yield improvements in Irish potatoes, beans, and maize respectively, would justify the cost of lime, assuming 50% subsidy provided to farmers.[10] Beyond costs, the long return on investment is discouraging to farmers- lime can take up from 6 months to two years to change the soil pH to an optimum level[11]. The reaction time of lime is directly linked to the quality (i.e., fine lime reacts with the soil quicker) and appropriate lime application. The low-quality lime – such as Grade II lime/travertine that was previously prevalent in Rwanda - and misinformation (e.g., on applying best practices, timing) can delay results, elongate the return on investment for lime, and increase farmers' misgivings on yield improvements. As a result, farmers often forego lime purchases in favor of other agricultural inputs, which yield quicker improved outcomes.

Over and above the lack of demand, supply chain inefficiencies at the extraction, processing and distribution stage, continue to hamper the growth of the industry. First, while the need to improve the quality of lime is well recognized, processors/lime producers currently lack adequate capacity to enhance the quality of lime, and low demand results in an unwillingness to invest in improved processor capabilities further. 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. With price-sensitive smallholder farmers and price-taker processors, high transportation costs are not always passed down to the end-consumer price; instead, transportation costs are more likely to reduce processors' and suppliers' margins, limiting the supply chain's economic viability. Third, 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.[12] 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.

The public sector has played a crucial role in strengthening the Rwandan lime sector, but policy and finance gaps continue to limit growth. There has been multistakeholder collaboration on soil acidity research; public institutions such as the Rwanda Standards Bureau have established quality standards; and there are established pathways to access lime through platforms such as Smart Nkunganire – the input subsidy technology platform. However, policy gaps continue to constrain the sector. For example, (i) the new distribution model regulations impose additional storage and package requirements on already resource and capacity-constrained processors. This is likely to worsen processors' ability to meet supply requirements; (ii) the absence of standards on lime application, undermines the ability to address soil acidity effectively and efficiently; and (iii) while there are finance gaps across the value chain, access to finance challenges is most pertinent at the production and end-consumption (farmer) levels thereby impacting optimal production output and demand for lime.

There is likely to be a limited appetite to address the challenges in the supply chain without addressing demand and the gaps in the enabling ecosystem. Demand is strongly linked to unlocking growth in the sector. The priority is to build and scale sustainable demand for lime. Supporting initiatives to build demand include (i) adopting a targeted and priority-based approach

[10] National Statistics Institute in Rwanda, Seasonal Agricultural Survey Annual Report, 2019; Dalberg analysis
[11] Stakeholder interviews (lime experts).
[12] Dalberg analysis; Nduwumuremyi et al (RAB), Mapping of limestone deposits in Rwanda and determination of quality of locally available limestone in Rwanda, 2017

to identify and treat soil with high acidity by revamping soil testing and updating research on the lime application and (ii) including application techniques and yield improvement estimates as part of existing awareness initiatives; and (iii) facilitating access to financing for farmers.

Addressing supply chain challenges will require solutions that target the unique needs of each supply chain actor. For instance, there are opportunities to earmark patient capital and leverage innovative financing mechanisms well suited to each supply chain actor's context for accessing finance. Further, based on an understanding of other comparable agricultural markets, there are opportunities to improve last-mile delivery and reduce lime transportation costs by (i) leveraging existing last mile distribution channel, establishing storage facilities – perhaps shared with other actors, and deploying technology to facilitate farmer awareness and physical access to lime, and (ii) working within the current public distribution model to embed proximity between the plant and demand hubs in the selection criteria framework. Lastly, Rwanda is well-positioned to ensure efficient lime use to optimize current lime reserves and engage neighboring countries in the lime supply chain, to ensure longer term supply of lime.

While the Rwandan lime ecosystem has active government support, there are opportunities to put in place or revise regulations and actively engage the private sector. For example, there e is a need to establish standards on appropriate lime use and application and adopt a phased approach to implementing the processor requirements stipulated in the new distribution model. In addition, there are opportunities to engage with the private sector to implement solutions. For example, implementing business intelligence and data-driven stock-management or geo-mapping software to optimize supply routes for distributors.

Contents

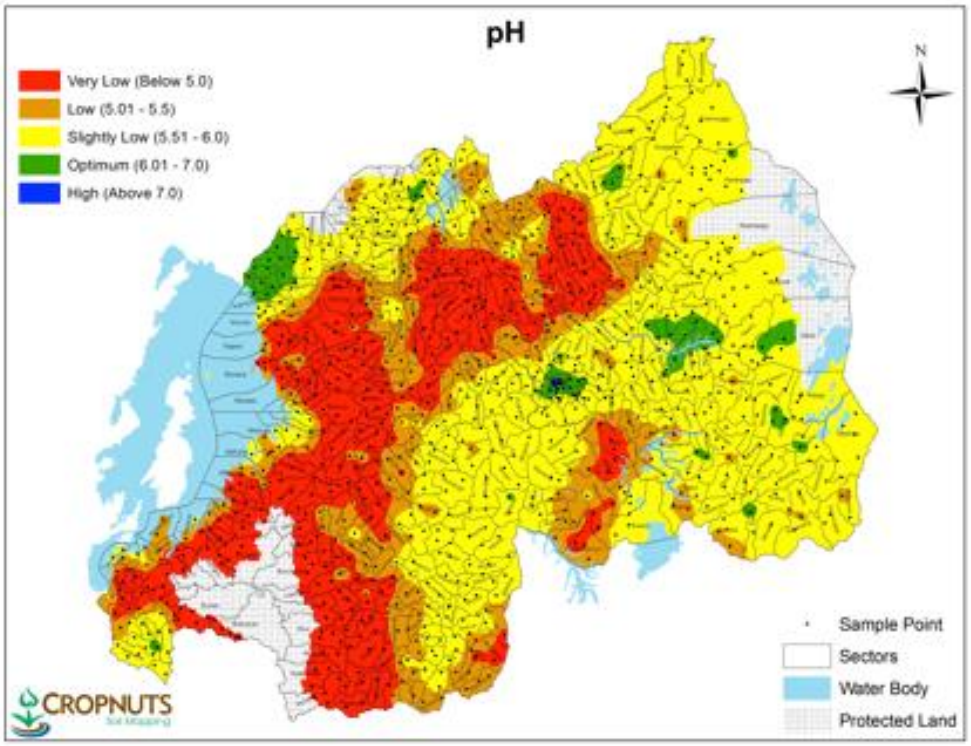
ABBREVIATIONS AND ACRONYMS

AGRA	Africa Green Revolution Alliance
APTC	Agro-processing Trust Corporation
BRD	Development bank of Rwanda
CaO	Calcium Oxide
CIMMYT	International Center for Maize and Wheat Improvement
COCHAUMA	Coopérative de Production de la Chaux de Mashyuza
DAP	Di-ammonium Phosphate
FRMS	Fertilizing Residual Materials
GAIA	Guiding Acid Soil Management Investments in Africa
GDP	Gross Domestic Product
GoR	Government of Rwanda
ISFM	Integrated Soil Fertility Management
MFI	Microfinance Institution
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Commerce and Finance
MT	Metric Tone
NGO	Non-Governmental Organization
NISR	National Institute of Statistics Rwanda
OAF	One Acre Fund
pH	Potential for Hydrogen/ Strength for hydrogen
RAB	Rwanda Agricultural Board
RALIS	Rwanda Agriculture and Livestock Inspection and Certification Services
RMB	Petroleum and gas Board
RSB	Rwanda Standards Bureau
SACCO	Cooperative and Saving Societies
SOFRECO	Consultancy for Sustainable Economic and Social Development
SOPAV	Société pour les aliments vegetaux
USAID	United States Agency for International Development
USSD	Unstructured Supplementary Service Data
VBAs	Village Based Advisors

I. INTRODUCTION

Rwanda faces significant and growing challenges with soil acidity. While different sources identify varying soil acidity levels, they all point to its prevalence in the country. For instance, RAB personnel report that nearly 47% of Rwandan arable land is acidic[13] - the equivalent of 540,500 ha out of the 1.15 million ha of arable land[14] - and about 26 out of the 30 districts have lands with pH levels between 4.5 and 5.5.[15] Figure 1 from the MINAGRI/RAB shows soil acidity levels in most Rwandan soil, implying that they have pH levels lower than 6.0[16] – which is the cut-off point for optimum level soil acidity, above which a vast majority of the more prominent crops in the country can grow seamlessly.[17]

Figure 1: Map of Rwanda showing soil PH levels across the country



Soil acidity deteriorates root growth and nutrient absorption, decreasing crop yield. In Rwanda, soil acidity is due to three main factors- i) parent soil material, ii) nitrification and iii) rainfall and leaching. First, soil originating from different materials varies in acidity over time, e.g., soil from granite – present in different parts of Rwanda – is acidic while soil from limestone is alkaline.[18] Second, applying fertilizer with a high nitrogen concentration can also increase soil acidity- acidity results from ammonium material such as Di-ammonium Phosphate (DAP) fertilizers – accounting for 30% of all fertilizers imports in Rwanda[19] - transforming to nitrate in the soil. As such, it is essential to note that soil acidity increases over time – with the application of fertilizers

[13] Stakeholder interviews (Government), 2021; Ruganzu, Improving crop productivity through wide scale promotion of lime and other ISFM technologies in the acidic soils of Rwanda, 2013
[14] Knoema Atlas, Rwanda arable land 1961 - 2020
[15] Ibid,
[16] Rwandan Ministry of Agriculture
[17] RAB/MINAGRI Soil Maps
[18] Oklahoma State University, Cause and Effects of Soil Acidity, 2017
[19] Africa Fertilizer, Fertilizer Statistics Overview 2013 – 2017

and high yield crops such as maize, beans, and potatoes that increase soil acidity at a faster rate.[20] Third, excessive rainfall, especially in finer soil, with cultivation on the hills and mountains of Rwanda, increases the risks of leaching.

Soil acidity has critical adverse impacts that threaten Rwanda's food security and agribusiness potential and reduces economic gains. Rwandan farmers depend primarily on rainfed crops such as maize, sorghum, beans, and tubers. They hand hoe their soil at least twice yearly, exposing it to erosion and rapid decomposition of organic matter. The impact of toxic elements disrupting nutrient absorption is lower crop yields or complete crop failure. Early studies on Rwandan soil show that lime application on different crops improved yield significantly- 1 t/ ha of lime applied in cassava increased yield by 12.6 t ha-1 (71%) while lime application rate of 4 t/ha in fields of beans, Irish potatoes, and maize increase yields by 1.27 t/ha (123%), 10 t/ha (71%), and 1.4 t/ha (63%) respectively.[21] Lower yields also contribute to overall agriculture loss and reduced economic gains:

- **Agriculture loss and inefficiencies**: In 2020, agriculture accounted for nearly a quarter of the country's GDP and was the primary source of income for ~70% of the population.[22]. However, agriculture remains by far the least productive sector – calculated by the sectoral GDP per worker deviation from the economy's average GDP per worker.[23] Achieving economic transformation of the agricultural sector in Rwanda requires improving productivity and thereby addressing any productivity inhibitors, including soil acidity
- **Reduced economic gains**: To feed the growing population, exploitation of all agricultural resources for sustainable agriculture and soil fertility improvement are crucial interventions. Food security remains an imminent challenge for the Rwandan food systems; a 2018 World Food Programme study showed that 18.7% of households are food insecure and 38.6% marginally secure[24]. Beyond nutrition, there is a need to engage farmers in market-oriented farming to increase crop yields to expand their incomes and improve their livelihoods; this requires increased surplus. On-farm consumption remains the main use of farmers' harvest; for instance, 62% of maize is consumed on-farm.[25]

Among viable solutions for managing soil acidity, lime is the most effective approach. Several solutions address soil acidity, including fertilizing residual materials (FRMs), acid-tolerant seeds, wood ash, and lime. FRMs such as Agro-100[26] combine fertilizing and liming components. FRMs have the competitive advantage of leveraging fertilizer purchase and distribution channels to ease the distribution of lime to farmers. FRMs also typically provide smaller, easy-to-carry packaging for farmers applying fertilizer and lime jointly – joint application of the two inputs resulted in improved yield in test trials in Rwanda.[27] The use of acid-tolerant plants has proven effective in rehabilitating soil areas with very low pH. Farmers may also use ash from burnt or commercial wood to address soil acidity; wood ash is more soluble and reactive than lime and has a quicker reactivity period; however, it requires larger

[20] Stakeholder interviews (Government)
[21] Nduwumuremyi et al, Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2014
[22] Statistica – Shares of Economic Sectors in Rwanda, 2020
[23] World Bank, Future Divers of Growth in Rwanda, 2019
[24] World Food Programme, Rwanda - Comprehensive Food Security & Vulnerability Analysis, December 2018
[25] NISR, Seasonal Agriculture Survey, 2019
[26] Nutriliming agents | FRM and alternatives to agricultural lime (agro-100.ca);
[27] Ruganzu, Improving crop productivity through wide scale promotion of lime and other ISFM technologies in the acidic soils of Rwanda,

volumes – nearly 2 – 4X the amount of lime needed[28]. This, in turn, worsens deforestation and its other soil debilitating consequences such as soil erosion. Liming is the most widely used soil acidity reduction approach; introducing lime (CaO) into the soil activates reactions that reduce toxins concentration in the soil. Among viable solutions for managing soil acidity, lime proves to be the most effective approach and achieve efficient agricultural output due to its availability, effectiveness, soil impact, and relative cost. Figure 2 compares the soil acidity solutions according to five metrics: the first four factors (soil impacts, availability, cost, and ease of use) are from the farmers' perspective while the climate impact is at a macroeconomic level.

Figure 2: Comparative assessment of soil acidity solutions managing soil acidity [29]

Factor	Fertilizing residual materials (FRMs)	Acid tolerant seeds	Lime	Wood ash
Soil impact	Neutralizes soil acidity over time	No impact on soil acidity	Neutralizes soil acidity over time	Neutralizes soil acidity quicker than lime
Availability	Not produced locally or regionally, therefore, limited access in the country, and imports are expensive	Limited availability in Rwanda	Widely available through natural lime deposits and small-scale processors	Given the large amounts of wood necessary and Rwanda's climate impact commitments, availability may be limited
Cost	High cost due to need for imports	Relatively inexpensive if produced in-country, high costs if imported	Lime is relatively inexpensive (cost of processing results in high end user prices)	Wood ash is relatively inexpensive unless it is commercially sold
Ability/Ease of use	Easier to use as it is in granulated form but requires additional application technical skills	East to use compared to soil acidity management methods	Lime in powdered form is difficult to apply to farms and handle; requires safety precautions	Wood ash is in powder form and is difficult to apply to farms and handle, requires safety precautions
Climate impact	Relatively ecologically sustainable	May contribute to increasing acidity of the soil	Releases carbon dioxide in processing and 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

[28] UNH Cooperative Extension, "Guide to Using Wood Ash as an Agricultural Soil Amendment",2018
[29] Nutriliming agents | FRM and alternatives to agricultural lime (agro-100.ca); The Guardian, "Oyster shells will give your soil a balanced boost", 2021; "Solutions to Soil Problems: Soil Acidity", 2019; UNH Cooperative Extension, "Guide to Using Wood Ash as an Agricultural Soil Amendment",2018

The Guiding Acid Soil Management Investments in Africa (GAIA) project is seeking to enhance its contribution to healthier soils and land management towards smallholder enterprises' development. This study is one of the numerous work packages that focus on the supply chain of lime. It sets out to identify the critical challenges in the supply side and identify opportunities to address the challenges. Further, the approach to evaluating the supply side considered challenges in the value chain and the enabling ecosystem, including policy, access to finance, etc. In brief, this study aimed to answer the following questions:

- What are the needs and ambitions of different supply chain actors?
- What are the key binding constraints to the effective supply of lime?
- What can be done to improve the supply of lime in Rwanda?
- What are some of the high-priority technical areas to build going forward?

For this study, we implemented a mixed-method approach. We leveraged interviews with experts and businesses in Rwanda, as well as reviews of publicly available data. The stakeholder engagements focused on understanding the constraints and opportunities for agri-lime in Rwanda through 12 stakeholder discussions, including with Government, private sector, NGOs/donors, farmer groups and experts. We also reviewed relevant policy documents, industry reports, and research documents, including policy and research documents on acidic soil management, proclamations, and regulations that govern the agricultural lime value chain, sectoral diagnostics reports, and market potential analysis. The Dalberg team then synthesized the collated data and research to generate insights and make recommendations.

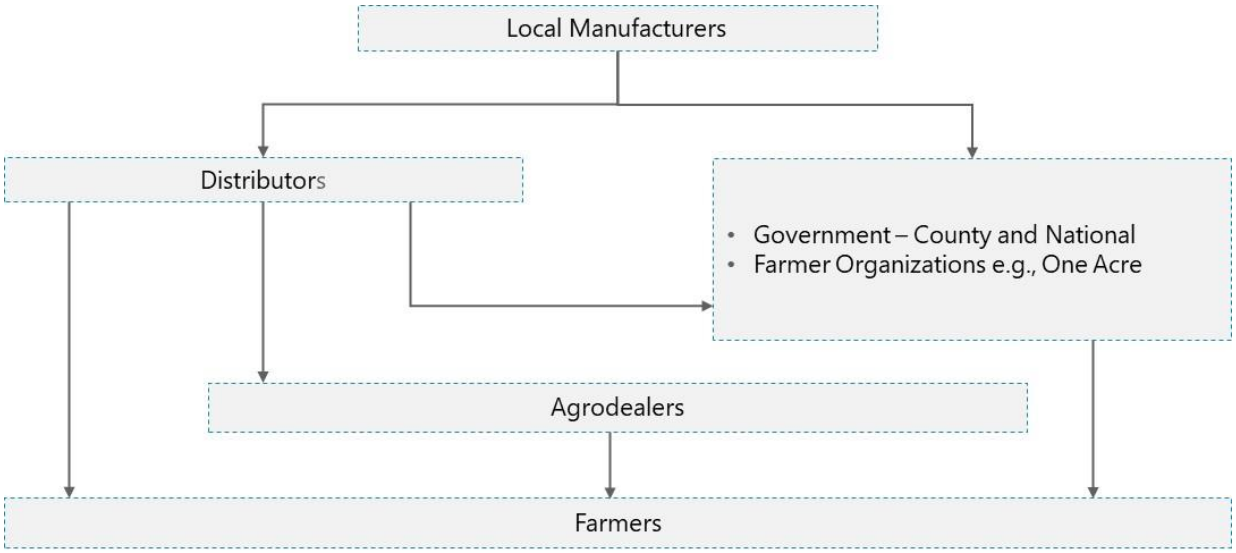
The purpose of this document is to generate an understanding of the supply chain that will feed into the subsequent phase of developing a national investment plan. Over a period of six weeks, we aimed to develop a clear understanding of the agricultural lime industry with a specific focus on the supply side. The next phase, focused on developing national investment plans for the Rwandan government, will draw from the insights from this work and the outputs from other work packages to delineate the investment needs of the lime sector.

While liming is a critical element to improve agriculture productivity and food security, it is important to place liming solutions within broader efforts to develop the sector. Soil acidity remains one of the numerous factors at play in agriculture sector development in Rwanda. As such, addressing soil acidity is by no means a panacea to addressing agriculture productivity. There are challenges across the agriculture value chain: limited access to improved seeds and fertilizers, minimal mechanization undercutting planting efficiency; post-harvest handling mechanisms and limited cold-chain facilities that lead to spoilage; and a need for improved market linkages. Thus, focusing on expanding lime adoption should complement rather than substitute other parallel efforts and investments to boost agriculture productivity.

II. Defining And Understanding The Challenges in the Supply Chain

Before considering challenges in the supply chain of lime, it is helpful to describe the key components and actors. As shown in Figure 3, while Rwanda's lime industry is nascent, the existing supply chain is relatively short, established, and driven largely by vertical integration.

Figure 3: Diagram/flow chart to show the distribution of lime in Rwanda



- **Local manufacturers:** The leading lime producers are located around the large reserves, e.g., ALICOMEC in Karongi, COCHAUMA (Coopérative de Production de la Chaux de Mashyuza), and APC Mashyuza in Rusizi, and SOPAV in Musanze.[30] These are small-scale processors who mainly specialize in agriculture lime and produce unburnt agriculture lime for local consumption. ALICOMEC – the leading agriculture lime producer – is the only processor specializing, at scale, in both agriculture and industrial lime– water filtration, cement production, etc.[31].

- **Governments and Farmer Based Organizations.** Demand in Rwanda is highly public-driven. Notably, the markets include public administrative units – primarily district offices, who secure lime on behalf of their farmer constituents and other farmer organizations such as One Acre Fund or APTC Rwanda, who source lime from manufacturers/processors on behalf of their farmer networks.

- **Distributors.** Distributors in the lime supply chain exist in different forms. These may be i) vertically integrated manufacturers, ii) farmer-based organizations such as One Acre Fund (OAF) sourcing directly from manufacturers and undertaking supply to farmers themselves iii) or independent entrepreneurs who bid for lime supply projects – particularly for the government, source the lime from the manufacturers and deliver them at different drop off points across the country.

[30] Stakeholder interviews (lime processors)
[31] Stakeholder interviews (lime processor – ALICOMEC)

- **Agro-dealers.** These are critical players who may be independent agro-dealers, affiliated with agro-dealer network organizations, or even commissioned by the government. They serve as the interface between farmers and lime distributors by providing advisory support to farmers on the use of lime and other inputs, as well as sell the inputs

Varying degrees of challenges in demand, supply, and the enabling environment constrain the growth of the lime industry. Demand is minimal and addressing limiting factors for demand will be a prerequisite to unlocking growth with the supply chain of lime in Rwanda. The supply chain has processors with technical and infrastructure challenges, distributors incur significantly high distribution costs, and there are concerns around the long-term sufficiency of the known lime deposits. Lastly, there are a set of requirements that further impede the involvement of small-scale and private processors as well as financing gaps that span across the value chain.

Figure 4: Synthesis of key binding constraints across the lime value chain

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 unwillingness to further invest due to low demand • **High transportation costs** as a result of diseconomies of scale and inconvenient 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 	• There are **policies and regulations that are misaligned with on-ground realities** • There are **financing gaps across the value chain** ranging from investments in processing equipment to farmers' financing or at least flexible payment schedules

Demand-side challenges

The public sector has played a critical role in jumpstarting demand for lime in Rwanda. AGRA and public institutions (RAB/MINAGRI) have conducted soil acidity studies and adopted a focused approach to addressing soil acidity in the last five years. Early results indicate that soil acidity is a pressing challenge to farmers' ability to produce certain crops. For example, the AGRA and other public institutions teams realized that farmers in the Southwest region were no longer growing potatoes due to high levels of soil acidity. As a result, addressing acidity and liming became a priority for the Rwandan agriculture sector[32]. The government has taken on the role of i) regulator – developing guidelines for lime use, ii) monitoring – to ensure lime is being used appropriately and tracking the crop yield impact over time, and iii) generating demand – primarily by subsidizing

[32] Stakeholder interviews (Government)

lime purchase by smallholder farmers and illustrating the use of lime to farmers. RAB, alongside MINAGRI, has initiated demonstration plots to illustrate the importance of liming as a practice**.** Alongside the government, other partners such as One Acre Fund (OAF) and Hinga Weze are currently working with agro-dealer networks to raise awareness on the need for lime application, particularly in the high acidity regions of the country.[33]

Despite the interventions of the public sector, uptake of lime remains low. Farmers use Smart Nkunganire System – a technology-based agricultural input subsidy system, to buy seeds, fertilizer, and lime from the government, at a subsidized price. Given the government's understanding of on-the-ground demand, t MINAGRI planned to distribute 50,924 tons of fertilizer and 15,211 tons of lime to farmers during the 2021/2022 budget year. [34] Assuming the targeted 45-60kg/ha of fertilizer[35] and the 1500-2,500kg/ha lime application rate (depending on the quality of lime[36]), this assumes that 848,700 – 1.13 million hectares would receive fertilizer while 6,080 – 10,140 ha received lime during the same period.[37] This suggests that lime application lags significantly behind fertilizer applications; yet yield improvement requires addressing soil acidity to improve the efficacy of fertlizer. This is in part because fertilizer awareness is more widespread among smallholder farmers in Rwanda and farmers.

OAF has also been involved in ensuring access of lime to farmers through leveraging its field offices and on-ground extension services to increase awareness of lime, provide lime on credit, and facilitate the supply of lime to farmers. Despite ongoing efforts, demand for lime still falls short, particularly compared to other agricultural inputs; OAF personnel estimate that less than 50% of farmers use lime.[38]

Figure 5: One Acre Fund farmers' adoption of lime

Case Study on Intervention in lime supply ONE ACRE FUND

- **Background**: One Acre Fund (OAF) has been serving as an input provider to a burgeoning segment of smallholder farmers in Rwanda, primarily farmers growing staple crops such as maize and climbing beans. Their unique value proposition is the organization's credit offerings on input purchases which are repaid upon harvest
- **Lime supply:** Like other inputs, One Acre Fund acts as a wholesaler and distributer of lime where they select a supplier based on quality and price, and transport it to their warehouses where they package it for sell in quantities of 25 kg packet size for application on 100 square meters of farming land
- **Demand:** Of the 800,000 smallholder farmers in the One Acre Fund farmer network, interviewed stakeholders estimate that less than half of the farmers add lime to their input purchase order.
  - Farmers often cite cost, transportation difficulty, and uncertainty on yield improvements as key factors deterring an increased uptake

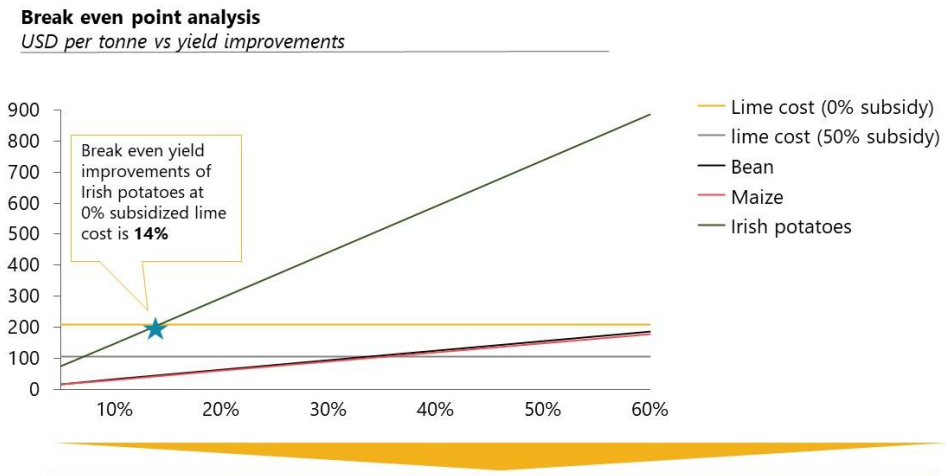
Prior to diving into supply chain constraints, it is critical to underscore that limited demand for lime is a key binding constraint to the efficient supply of lime, affecting soil acidity, crop yield, and food security

[33] Stakeholder interviews (NGOs)
[34]The New Times, Farmers worried as fertilizer prices rise, 2021
[35] Ilbid.
[36] Stakeholder interviews (Government)
[37] Dalberg analysis
[38] Stakeholder interviews (NGOs)

Cost is one of the biggest deterrents of lime uptake for an average smallholder farmer. Large quantities of lime are required to treat acidic soil, and this presents a significant expense incurred by farmers. Smallholder farmers would need to pay retail prices ranging from US$ 0.1-0.14 per kg[39] for an estimated 1.5 tons of Grade 1 lime per hectare; less than the 2.5 tons per hectare required for Grade II lime[40]. Given that Rwanda already provides subsidies, there are limitations to further reducing the cost of lime to farmers, without addressing cost inefficiencies across the supply chain and achieving economies of scale, and gradually decreasing lime unit costs. Growth opportunities are more likely to emerge through communicating the value of lime in terms of improved crop yield and incomes, which requires improved quality of lime, awareness of correct application methods, and timing of application.

Effective communication of the value of lime requires understanding cost versus benefit of liming. Yield improvements vary substantially and remain unqualified by some of the main organizations in the supply of lime in Rwanda, including the RAB; in part, because achieving yield improvement is dependent on a range of factors, beyond addressing soil acidity. Based on high level break-even analysis, a 7%, 33%, and 35% yield improvement in Irish potatoes, beans, and maize yield (respectively) is sufficient to offset the cost of lime, assuming lime is subsidized by 50%. RAB/MINAGRI estimate that the average sufficient lime application rate of Grade I is 1.5MT/ha compared to 2.5 – 4 MT/ha of Grade II which was previously more commonly used in Rwanda. A study (assumed to be using Grade II lime) demonstrated that applying 4 tones/ha in farm fields increases yields by 71% in Irish potatoes, 123% in beans, and 63% in maize [41] which surpass the breakeven points for yield improvements considering the cost of lime applied.

Figure 6: Yield improvement break even point by crops [42]

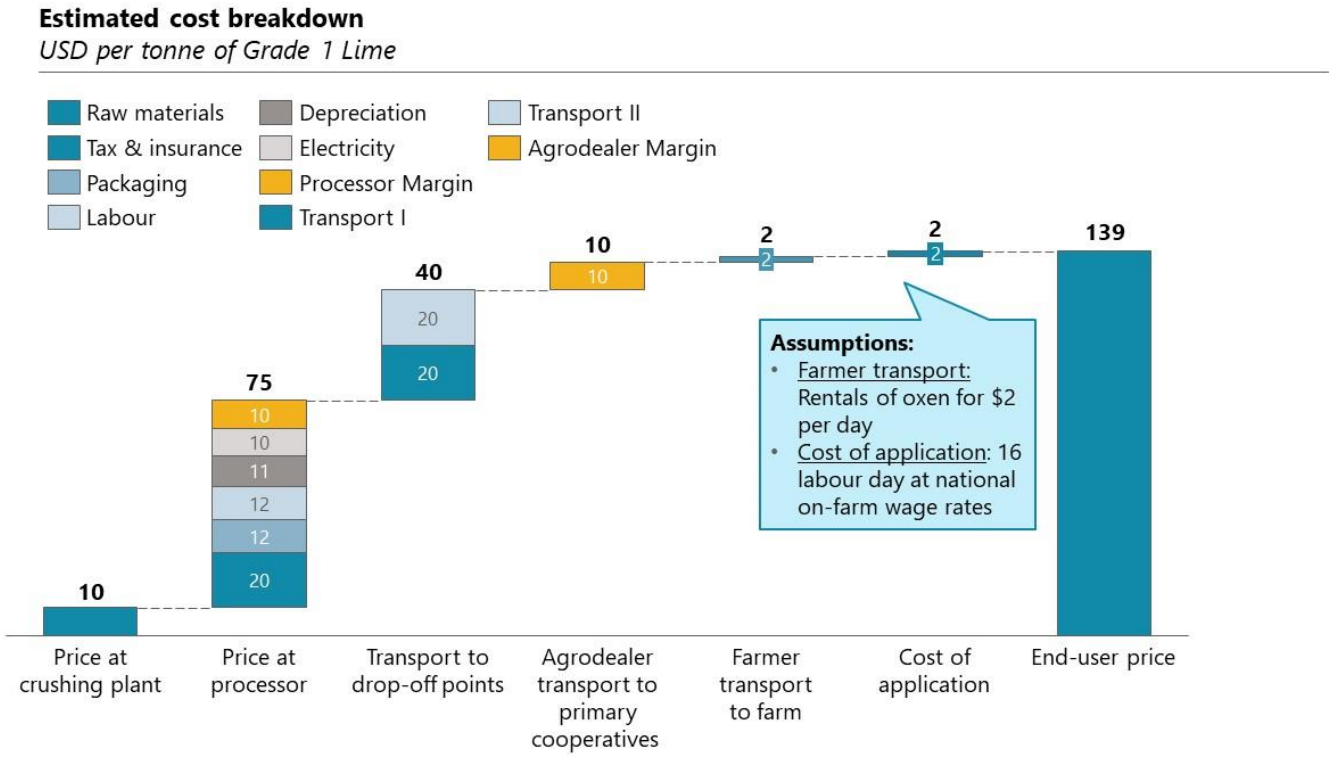


Break even point (% yield improvements)		
	0% subsidy	**50% subsidy**
Bean	67.4%	33.7%
Maize	70.7%	35.3%
Potatoes	14%	7%

[39] Stakeholder interviews
[40] RAB Workshop Presentation – 16 July 2021; Stakeholder interviews (lime processors)
[41] Nduwumuremyi et al, Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2014
[42] National Statistics Institute in Rwanda, Seasonal Agricultural Survey Annual Report, 2019; Dalberg analysis

The high cost of lime is primarily driven by extraction and processing, which accounts for ~65% and high transportation costs. At the extraction and processing stages (see Figure 7), packaging and labor cost form a significant proportion of excavation cost partly due to diseconomies of scale.[43] Moreover, lime drop-off points are often at central locations such as district offices which requires farmers to bear the cost of last-mile distribution to their farms. While the additional cost is not astronomical, estimated at $2 per day to rent a bike or farmers will carry the lime themselves, the amount of lime required coupled with the distance acts as a significant disincentive to fetch lime from drop-off points and use it on the farm[44].

Figure 7: Cost breakdown of lime from production to end consumer[45]



Given that market is mainly public-driven, supply chain actors are largely price takers. Processors, who also undertake limestone excavation, typically set prices depending on their cost structure when sourcing lime to individual organizations, for example, farmer cooperatives and farmer-based organizations. However, when sourcing to public markets, district offices have historically launched individual tender bidding processes which select suppliers based mainly based on prices. Tender winners are not required to be processors themselves; those that are not processors, source from processors, contingent on their ability to meet the price structures proposed in the bidding process. As a result, processors often become price takers in public market lime supply projects because (i) there is high competition from other small-scale processors, and (ii) there is a government monopsony, with an end-consumer price target, to minimize farmers' cost burden. As a result, there is an expected $10 margin/ton for processors and $10 margin/ton for agro-dealers

[43] RAB Workshop Presentation – 16 July 2021; Stakeholder interviews (lime processors)
[44] Stakeholder interviews (farmers)
[45] Notes: The end price is estimated at $115/MT however the graph assumes that the additional $20 from transport is passed on to the end consumer. Sources: Stakeholder interviews

that distribute lime to farmers. On the other hand, distributors set the distribution price. In terms of transportation cost, it is worth noting that the processors stated transportation costs are twice the amount indicated by RAB and MINAGRI- government quotes transportation costs at 20 US$/ton while processors estimate transportations costs at US$ 40/ton).[46]

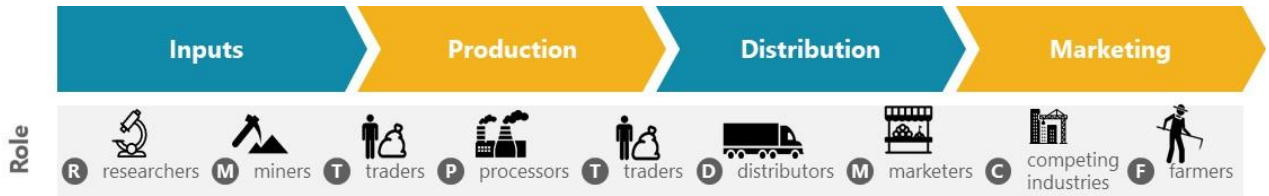
Moreover, farmers are cash-constrained, and other soil preparation costs often prove too cumbersome for farmers. For instance, lime application requires prior soil testing, which imposes additional costs. However, accessible soil testing ensures accurate knowledge of the level of acidity in the soil, thereby enabling farmers to apply the required quantity of lime, thereby resulting in cost savings by avoiding over-application of lime in less acidic soils. A lack of cash and limited options of financing in the rural economy limit soil testing and further constrain uptake. Furthermore, the need to pay for lime before harvest imposes an additional burden on already financially constrained farmers.

Beyond costs, inadequate quality of lime further constraints demand. The reaction period for lime is highly dependent on the physical quality of lime. Depending on the fineness of lime, reaction time can range from 6 months to two years[47] to change soil pH, and reapplication is needed to maintain soil health and reach optimum pH. This imposes additional lag time in achieving improved yields and hence, delayed return on investment of lime application. It is important to note that the reaction time directly links to the quality of lime (i.e., fine lime reacts with the soil quicker) and appropriate application after receiving the correct information. Low quality is particularly pertinent to Rwanda's lime supply because Grade II lime –lower caliber travertine - was prevalent, even distributed through public distribution channels, before its recent ban. Information asymmetry may further elongate the return on investment for lime if they are not applying lime appropriately (e.g., following best practices such as broadcasting or applying it at the wrong time of the planting cycle), which further increases farmers' misgivings on yield improvements.

Supply-side challenges

On the supply side, the lime sector faces numerous challenges across the value chain, affecting the quality and availability of lime. The identified challenges are based on the distinct stages of the supply chain- (i) inputs – limestone excavation, production/processing of limestone into high-quality lime; (ii) distribution; and (iii) marketing of lime to farmers.

Figure 8: Supply chain breakdown



[46] Stakeholder interviews (lime processors)

[47] *Notes: A 160-hour monthly wage of an on-farm labor worker in rural areas is %18,600 – an approximate of $1.2/hour.
Source: Nduwumuremyi et al, Rwanda Quality Lime Production, 2017; RAB Workshop Presentation – 16 July 2021; National Institute of Statistics in Rwanda, The Fifth Integrated Household Living Conditions Survey, 2016/2017; Stakeholder interviews (lime processors and farmer organizations)

Inputs

While the overall chemical quality of limestone – the level of CaO and MgO - is good, the processing of lime often undermines its physical quality. The larger and more reliable reserves of limestones are found in the Western (Karongi and Rusizi districts) and the Northern (Musanze district) provinces. Smaller deposits exist in Gakenke and Rulindo districts[48]. Early records dating back to 2001 (SOFRECO study) show an estimated 18 million cubic meters – 6.35 million tonnes – available in Rwanda.[49] Agriculture lime accounts for over 95% of the volume of lime extracted in Rwanda. [5051]. A few dolomite sites (mined for MgO) are typically used in tea plantations. Some deposits, such as Gitesi and Gishyita in Karongi, have been discarded due to low quality or inconsistencies in quality (low concentration of CaO or high variability)[52]. Despite the good chemical quality, limestone deposit products are still below acceptable fineness levels due to inadequate processing mechanisms- technical know-how and equipment.

"The – chemical- quality of our limestones is good enough, however, it is the physical quality that is lacking resulting from less advanced processing mechanisms" – Rwandan small scale lime processor

Processors express concerns of depletion in the short term. Based on different acidity levels of each district, the 6.35 million tones available in-country is estimated to last 15.5 years[53] - assuming a once-off country-wide application and subsequent annual reapplication at 0.5MT/ha after soil pH reaches at least 5.2 [54]. However, there is presently limited discourse on interventions to ensure adequate supply for agricultural lime in the long run.

Figure 9: Lime requirement (or needed amount) for soil acidity rectification in Rwanda

Rwanda provinces	**Approximate acidic areas(ha)**	**Soil pH**	**Exchangeable Al** (cmol/kg)	**Max Lime required** (t/ha)	**Required lime** (t/province)	**Required lime to maintain health** (t/province)
Southern	144,906	4.1 – 5.4	0-3	4.5	634,863	72,454
Western	156,510	4.3 – 5.4	0-3	3 - 4.5	655,793	78,255
Northern	122,143	4.7 – 5.4	0-3	4.5	549,600	61,067

[48] Nduwumuremyi et al, Mapping of limestone deposits and determination of quality of locally available limestone in Rwanda, 2017
[49] Ministry of Industries and tourism, Evaluation and classification of travertines deposits SOFRECO (2001). Kigali, Rwanda:
[50] Nduwumuremyi et al (RAB), Mapping of limestone deposits in Rwanda and determination of quality of locally available limestone in Rwanda, 2017; Stakeholder interviews
[51]Notes: The Ca (%) and Mg (%) were analyzed by ethylene diamine tetraacetate (EDTA) method (Hesse, 1971), the titration was done with EDTA 0.01N. The CaO (%) and MgO (%) were determined by multiplying Ca with conversion factor of 1.3992 and Mg with conversion factor of 1.6578 (Marcus, 2009).; Source: Ibid
[52] Ibid.
[53] Ministry of Industries and tourism, Evaluation and classification of travertines deposits SOFRECO (2001). Kigali, Rwanda:
[54] Beernaert FR (1999). Feasibility study of production of lime and or ground travertine for management of acidic soils in Rwanda. ProInter Project Consultants, Brussels. p. 250

Eastern[55]	141,796	5.1-5.4	0-2	3	363,006	52,121
Kigali	5,739	5.1-5.4	0-2	3	17,218	2,870
Total					**2,220,480**	**266,767**

Production / processing of lime

Processors are small and often have limited capabilities which impact the quality of lime produced. Key stakeholders interviewed indicated that lime quality drops at the processing stage. Similarly, processors also cite capability challenges – both technical know-how and physical infrastructure, mainly equipment to uphold physical lime quality particularly pertaining to achieving the desired lime fineness levels. :

- **Technical know-how:** For instance, ALICOMEC attributes other processors' inability to tap into the industrial lime space to limited technical know-how. Similar technical gaps exist when it comes to more sophisticated agriculture lime processing, e.g., granulated lime.[56]
- **Physical infrastructure**: Processors excavate limestone, and they typically use firewood or charcoal to burn the limestone into lime. This is a carbon-emitting process; the use of petroleum coke would be an alternative that reduces the emission of the lime preparation methods. An alternative to burnt lime is unburnt lime – which many processors have resolved to use – and RAB has been urging processors to utilize crusher machines. However, some key processors – APC Mashyuza and SOPAV were only able to acquire processors after receiving support from AGRA. A particular processor was forced to delay production timelines due to an inability to access financing for installing crushing machines.

The processor capability challenges point to underlying financial constraints. Investments in lime processing may exceed the financial capabilities of small-scale processors. For instance, the dryer and crusher machines can cost up to $90,000 - nearly $60,000 to invest in a crushing machine, and the installation costs start at $15,000 and can reach $30,000. Currently, financing options are limited to commercial financial institutions' product offerings, including asset-based financing, at higher interest rates of ~17%.[57]

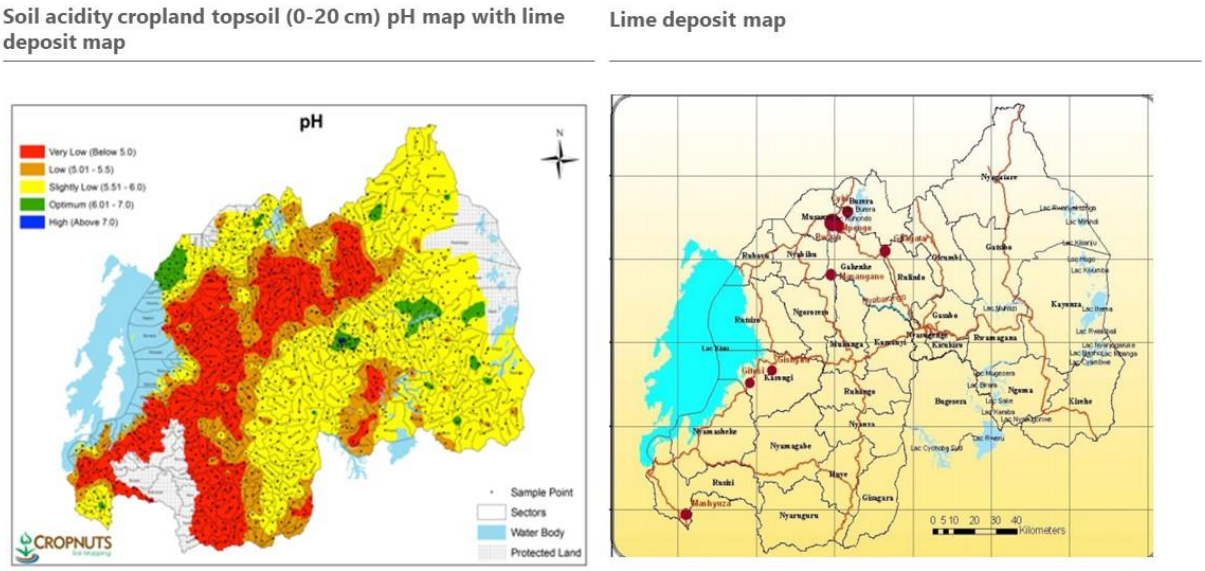
Distribution

Lime reserves are located near acid soils which should indicate ease of distribution. The largest deposits, and similarly the regions with the highest acidity (as shown on the pH map of Rwanda), tend to be in the North and Western provinces. The Southern province also has some highly acidic districts, notably Nyamagabe and Nyaruguru districts. These regions also i) have some of the most population-dense districts after Kigali, including Rubavu, Musanze, Nyabihu, and Burera, implying a higher concentration of smallholder farmers[58], and ii) are critical food baskets

[55] Eastern province pH levels are relatively higher except the Gatsibo district with a 4.7-5.5 pH range
[56] Stakeholder interviews
[57] Stakeholder interviews (Lime processors)
[58] Rwanda National Census 2012

for the country high productivity and share of national agriculture output, e.g., Northern province has the highest maize yield/ha of all provinces in Rwanda.[59]

Figure 10: Side by side comparison between regions with high soil acidity and limestone deposits[60]



However, poor infrastructure and low demand result in low lime quantity, increasing unit transportation costs. According to processors, transportation can reach nearly $40/MT, where the end price of lime is $115/MT. These high transportation costs are typically due to the poor infrastructure where distributors hike prices to increase the return of transporting bulky lime on rugged roads. Distribution is conducted by third parties when processors are not vertically integrated. In these cases, there is a set price (as is typical of government contracts), squeezing processors' margins and rendering the supply chain less commercially viable for small-scale processors.

Moreover, there are no storage facilities at drop-off points to allow for economies of scale in the transportation of lime. For instance, district purchase orders fall in the range of 3000 – 4000 MT, surpassing any storage capacities at district levels. As a result, lime is distributed in smaller quantities or stored in open-air at drop-off points which further undermines its physical quality and leads to product loss, with powdered lime that is susceptible to wind.

Marketing

The public sector drives demand generation while the private sector is engaged in manufacturing and distribution. Commercial farmers are the vast majority of agriculture lime clientele because they have offtake obligations that impose high value on ensuring optimal yields, and they have the financial means to invest in high-quality inputs. However, in Rwanda, 95% of farmers are smallholder farmers, with varying and often minimal access to formal market channels and with less disposable incomes. As a result, the government accounts for the vast majority of lime offtake, where they procure lime to distribute to smallholder farmers - through the national input distribution program – and extend a 50% subsidy to farmers. To ensure the marketing of

[59] PSDAG, Maize value Chain Analysis 2013

[60] MINAGRI/RAB soil acidity maps; Nduwumuremyi et al, Mapping of limestone deposits and determination of quality of locally available limestone in Rwanda

lime, the government seeks to fulfill its three main roles: regulation, monitoring of quality standards, and ensuring timely delivery of lime to farmers.[61]

- **Regulation:** Agriculture government institutions such as RAB and MINAGRI provide certifications for processors and lime suppliers per standards set by a coalition of stakeholders, primarily the Rwanda Standards Bureau. RAB/MINAGRI also earmark funds for district offices to use for lime application. While MINAGRI and RAB have established quality standards, they currently do not monitor whether the lime supplied is compliant with the quality standards.
- **Monitoring of quality:** The district offices identify liming needs and secure funding. The districts conduct independent procurement by launching tenders for suppliers to distribute lime to their farmer constituents. With this model, district offices face two main challenges: (i) acquiring high-quality lime that ensures high yield, e.g., the most widely available lime was Grade II which is inferior in quality but cheaper than Grade I [62] (ii) successfully collecting farmers contributions (50%) to feed into the revolving fund at the Ministry of Finance.
- **Timely delivery to farmers:** Processors and independent entrepreneurs bid and win for district tenders. They then deliver lime to farmers and agro-dealers – who, in addition to lime supply, also conduct sensitizations efforts towards encouraging uptake of lime within farmer groups. Suppliers then provide delivery notes and are compensated 100% by districts. A persistent challenge with this delivery model, at least from the perspective of processors, is that tender winners don't need processing capacity, and thus i) processors are price takers with an additional middleman, and ii) there are glaring quality gaps.

"I once had an offtaker agreement with an independent distributor. While their delivery order was 3000 MT, they sourced only 1,500 MT from me, and to the best of my knowledge, they did not have other lime source origins. This implied a dilution of lime quality delivered"

*– Rwandan small scale l*ime processor

Recognizing these challenges, the GoR revised its lime supply model to improve lime quality and processing standards. The changes, effective August 2021, are focused on addressing some of the challenges embedded in the previous distribution model, particularly around quality of lime, effective farmer contribution collection model, and more actively engaging the private sector in the lime supply chain[63]**:**

- **Ensure alignment between government standards and quality of lime:** MINAGRI/RAB will take over the bidding process and select processors in line with quality and processing.
- **Ensure high-quality lime supplied at drop-off points:** Grade I lime will be the only permitted lime type distributed to farmers. RAB will then be responsible for inspecting the quality of lime at the lime suppliers' storage space before distribution.
- **Streamline processes to collect farmer contributions:** District offices are exempted from farmer contribution collection. Farmers pay their 50% contribution directly to lime supply providers.

[61] Stakeholder interviews (Government, Lime Processors)
[62] Notes: MINAGRI and RAB report that "Grade II is of the lowest quality and hence the cheapest lime. Suppliers of this low-quality lime usually win tenders at the District level. Grade II lime supplied to districts, though the cheapest, is of low quality with little effect on crop productivity". There were no noted availability constraints for Grade I lime.
Source: RAB/MINAGRI workshops on lime distribution model, 16th July
[63] Ibid.

- **Engage processors in the distribution chain:** Processors now presumably have a competitive advantage in the bidding process as processing capabilities will be a key criterion. Suppliers will be required to demonstrate the capacity of producing 10,000 MT complying with Grade 1 lime specification. Moreover, lime suppliers will be expected to show the capacity to store 10,000 MT annually and package the lime in laminated bags with clear labels around the origin, content (moisture content, fineness, composition in terms of CaCO3, MgCO3), weight, company details, and the expiry date).

Challenges in the enabling environment

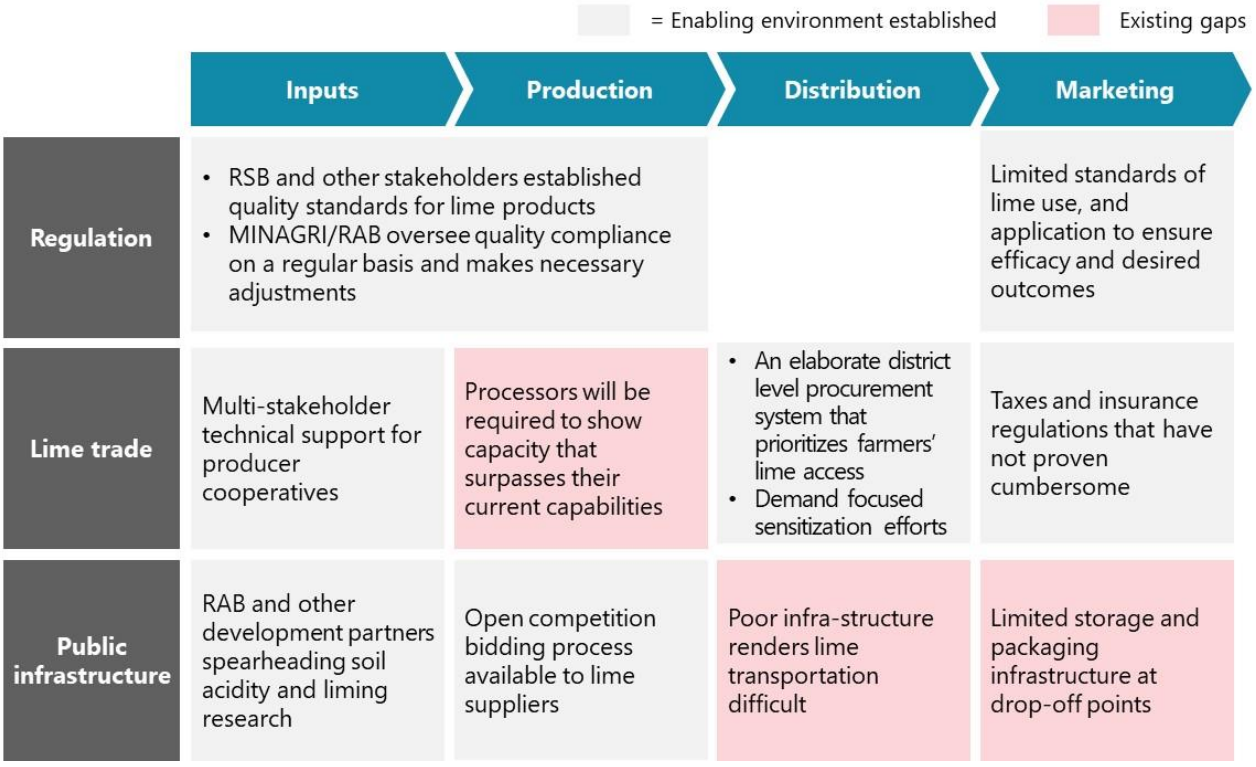
The regulatory framework is largely supportive; however, some policies are likely to further constrain growth in the sector. In particular, the revisions to processing requirements, under the new distribution model, are likely to introduce additional challenges in the supply chain. For example, the storage and packaging capabilities are likely to be hard for processors to acquire over a short period at the production stage. Processors could reach the 10,000MT as the more active processors have 15MT/day capacity for an 8-hour shift; increasing production to the target scale may only require increasing production time to 16-work hour days[64]. However, expanding storage and packaging capabilities imposes additional capital expenditures and operating costs that require immediate funding. Moreover, processors are expected to make these investments before winning the open bidding competition and securing guaranteed public sector demand.

Similarly, an absence of lime application policies also imposes challenges. There are set standards for other inputs' usage (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.[65] However, similar standards do not exist, and the guidelines on which different stakeholders agree, are not widely disseminated

Moreover, inadequate public infrastructure hinders the efficient delivery of lime. For instance, poor roads hike up the prices of transport that in turn either increase the end price or squeezes the processors' margin; the latter is more likely as i) demand is monopolized by the public with leverage to set end prices, and ii) smallholder farmers are price sensitive. Other shortcomings in the public infrastructure are limited storage points at drop-off points where neither administrative space (e.g., the district offices) nor agro-dealers have sufficient storage or warehousing facilities, if any at all.

[64] Stakeholder interviews (lime processors)
[65] RSB support towards food safety presentation by the National Certification Division, 2015

Figure 11: Synthesis of the enabling environment (Policy and regulatory framework)



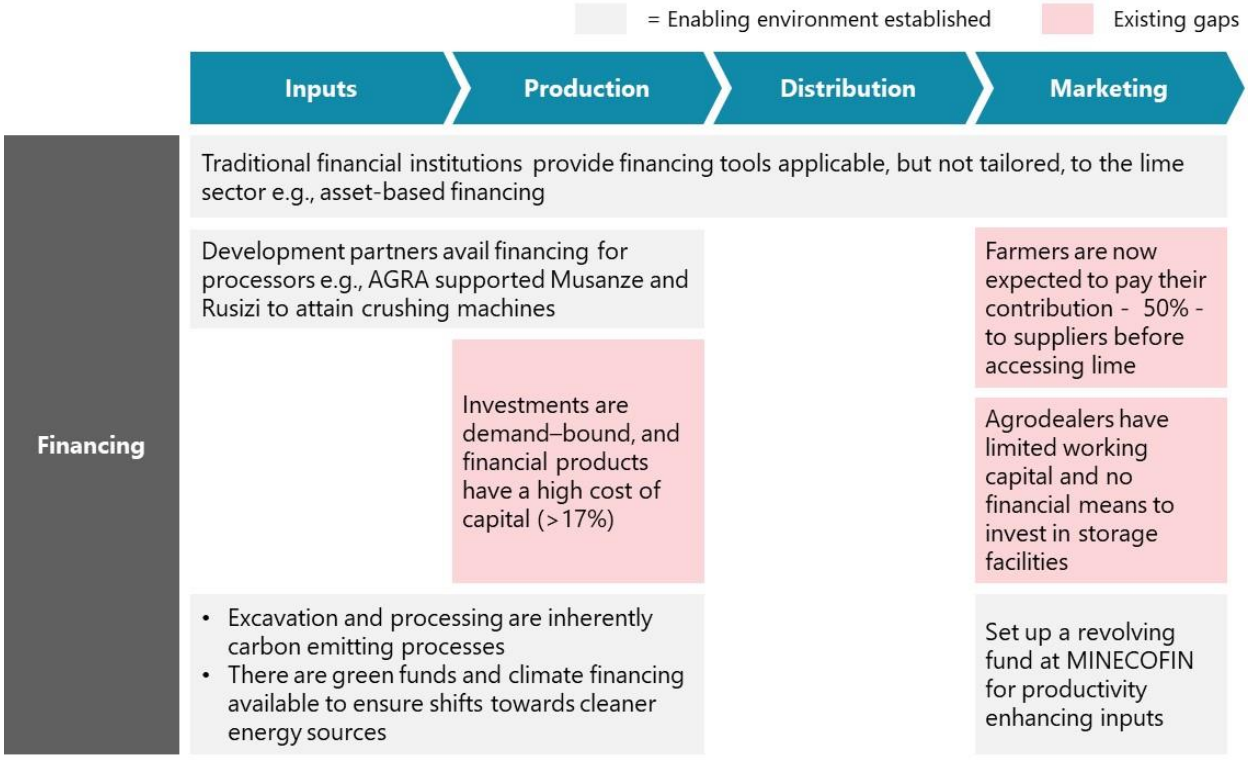
Limited access to finance has desperate effects on for the various supply chain actors. For instance, distributors do not have prominent financing challenges, while lime excavators and processors, farmers, and agro-dealers have unique challenges:

- **Lime excavators and processors:** Processor requirements will only exacerbate their need for financing; however, access to capital from traditional financial institutions remains limited due to a range of factors: i) There is a high cost of capital that typically exceeds 17% interest rates which minimizes processors' lending appetite; ii) given bourgeoning demand, there is difficulty in securing sustainable offtaker markets which further complicates financial institutions' job to project revenues that allow the processor to service financing obligations, iii) the small-scale processors' professionalism (financial records, board and leadership) and experience may also be subpar for enterprises in their nascent stages
- **Farmers:** Larger and medium-size farms already have a measure of finance in place for inputs. These include actors such as Agro-processing Trust Corporation (APTC) Rwanda and horticulture operators such as Garden Fresh. However, these large and medium commercial producers are few in Rwanda. The next category of farmers is farmer cooperatives, particularly those with buyer arrangements that have stringent quantity and quality requirements and may be more willing and able to purchase lime. This second category also does not have financing gaps because microfinance institutions readily serve these constituents. Independent smallholder farmers on the other hand have cash flow constraints and generally rely on flexible payment schedules e.g., payment after harvests. 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[66]. Thus, there is a risk that non-flexible payment schedules may induce a drop, at least in the short-term, in lime uptake.

[66] RAB/MINAGRI workshops on lime distribution model, 16th July

- **Agro-dealers:** Farmers will be sourcing lime from agro-dealers who neither have the cash flow to provide lime on favorable credit terms nor the financial capabilities to improve their storage capacity and sell inputs including lime at higher volumes.

Figure 12: Synthesis of the enabling environment (Financing)



Identifying the needs and ambitions of different supply chain actors, and ways in which they are falling short of achieving them, provides an alternative perspective to assess supply chain challenges. While there are supportive capabilities and systems in place for different supply chain actors, there are demand, capabilities, information, and policy constraints impacting the full realization of each.

Figure 13: Synthesis of supply chain actors' needs and existing gaps[67]

Supply chain actors	Needs and ambitions	Existing capabilities and gaps
Input/Excavators	• Technical know-how and equipment to ensure efficient excavation • Consistent supply of lime in the short and long term • Assured uptake from processors	• The chemical quality of limestone is at par and processors do not indicate excavation processor limitations • There are concerns about the short-term depletion of limestone in Rwanda • Vertical integration (i.e., all processors also own excavation sites) ensures uptake of excavated limestone

[67] Stakeholder interviews (all)

Processors	• Technical know-how and equipment to ensure the high physical quality of lime • Warehouse and storage capacity to plan production with inventory • Appropriate packaging and labeling to maintain and communicate the quality of lime distributed • Assured uptake from distributors and/or assured demand from end-consumer users	• Development partners have observed gaps within processors' technical know-how on preparing top-tier lime quality • Existing finance gaps including capital to invest in processor infrastructure, as well as short-term working capital as demand increases • The open bidding competition is a pathway to attaining public markets, while ensuring transparency, does not guarantee demand • There are demand constraints that are a function of costs, farmers' understanding of lime value for money, quality of lime, etc.
Distributors	• Better road infrastructure and vehicles to ensure seamless transportation of lime • Appropriate packaging to ease transportation of lime minimizing losses while distributing lime • Clear routes to ensure last-mile delivery of lime to farmers • Assured demand from agro-dealers and farmers which yield economies of scale and reduced per tonnage costs	• Poor infrastructure complicates and renders transportation of lime expensive • Inappropriate packaging where lime is typically exposed due to processors' limited capabilities • There are linkages between distributors and agro-dealers through the government-backed input subsidy program. Besides some farmer organizations and projects undertake their own lime distributions to constituents • There are demand constraints which are a function of costs, farmers' understanding for lime
Agro-dealers	• Platforms to build up demand around the lime and incentivize farmers' uptake • Storage capabilities to work around potential cases of lime carry over or delayed uptake	• Demonstration plots are focused on other more prominently used inputs – improved seed and fertilizer. These plots are concentrated in areas with previous development partners' support e.g., Southwest Rwanda • Limited storage capacity at the agro-dealer level and drop-off sites for farmers • Limited standards set and communicated around lime use
Farmers	• Access lime at affordable costs and of high quality • A better line of sight into the expected yield improvements of applying lime	• Lime distributed has previously been of lower quality (Grade II) but there is a recent ban on low-quality lime • There are information gaps on yield improvements to be expected

	• Technical know-how on the use and application of lime	after applying lime; value for money is one of the most compelling means to create an appetite for input adoption • There are information gaps on the best practices for applying lime

III. RECOMMENDATIONS TO ADDRESS THE GAPS AND ADVANCE THE SUPPLY OF LIME

A thorough understanding of the supply chain and its main challenges provides the basis for the recommendations considered in this report. The focus is on developing disaggregated and actionable recommendations, highlighting the role of various stakeholders (public sector, private sector, development partners, etc.)

Figure 14: Synthesis of opportunities addressing lime supply in Rwanda

Binding constraints	Challenges	Opportunities
Demand 	• **Demand remains minimal** due to various challenges and as a result, the market is public-driven	• Focus interventions on high-impact areas • Emphasize on the how alongside the 'why' in sensitization efforts in high demand regions.
Supply 	• Producers **currently lack the capacity** (processing, warehousing capacity, packaging etc.) • **High transportation costs** increase end price (demand) or limit economic viability for suppliers • Rwanda has an expiry date to its known limestone deposits	• Earmark patient capital and leverage innovative financing mechanisms for supply chain actors • Leverage supply routes, on-ground facilities, vertical integration, and technology to facilitate farmers' physical access to lime • Embed proximity in the lime supplier selection criteria • Engage neighboring countries in the lime supply chain
Enabling environment 	• **Missing /misaligned policies and regulations** e.g., on lime application standards, new distribution model processor requirements • **Financing gaps** across the value chain primarily including farmers	• Set policies around lime use, and application • Adopt a phased approach to achieving new processing requirements • Engage the private sector to further strengthen the enabling environment

Demand-side opportunities

Limited demand for lime is driven by a core set of interconnected factors, including cost, low quality of lime, and soon, access to finance. In addition to these core constraints, ongoing initiatives need to be ramped up to achieve widespread demand on lime, such as awareness and sensitization efforts, demonstration plots, and other approaches to improve technical knowledge around lime application. As a result, our overarching recommendation is to build demand by prioritizing activities and interventions efficiency of ongoing initiatives.

Target interventions and improve awareness

1. Focus interventions on high-impact areas

Focusing on high need and high priority soils will be critical to improving efficiency. Given competing priorities and resource constraints, a prioritization-based approach will be essential to maximizing lime supply's soil health and yield impact. This year, the government reportedly had a US$ 30 million funding deficit in funding the supply of lime to smallholder farmers.[68] Based on our engagement with government stakeholders, this prioritization approach is well placed in existing plans to identify and prioritize districts to receive lime.

To successfully enable prioritization, it will be critical to improve farmers' application of lime by (i) revamping soil testing at farmers' fields, and (ii) update research on lime application on soil acidity and launch new studies to improve the shared understanding of the application of lime:

- **Revamp soil testing**: MINAGRI and RAB have already developed country soil maps detailing the pH levels and mineral composition. Regular sample soil testing, especially in highly cultivated regions, as acidity increases with continuous cultivation, and fertilizer application, will be vital to ensuring that the liming practice remains efficient. Currently, RAB oversees soil testing on a national level and the institution has rolled out innovative initiatives such as the Caravan – a $1 million mobile soil-testing laboratory project. Beyond public institutions, farmer cooperatives also support their constituents with soil testing, and at times free of charge.[69] 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.[70] Private actors in the region such as Kenyan AgroCares are also taking pioneer strides in rolling out technologically backed and technologically advanced soil testing tools (Figure 15).
- **Update research on lime application:** Beyond prioritizing regions, a prioritization approach also includes understanding how the application of lime may vary from one region to another depending on, for instance, soil acidity and mineral composition. The GAIA project and RAB intend to collaborate on a study that delineates optimum quantities applied for different regions in the country depending on the soil properties. While prior studies have deduced a range of application quantities[71], there is a need for a more empirical analysis of application quantities to achieve optimum results.

[68] New Times, Agriculture suffers Rwf30bn funding deficit to roll out lime, 2021

[69] Stakeholder interviews (

[70] Desert Cart South Africa, SONKIR Soil pH Meter, MS02 3-in-1 Soil Moisture/Light/pH Tester Gardening Tool Kits for Plant Care, Great for Garden, Lawn, Farm, Indoor & Outdoor Use (Green)

[71] Nduwumuremyi et al (RAB), Soil acidity analysis and estimation of lime requirement for rectifying soil acidity, 2017

Figure 15: A case study on an innovative soil testing mechanism[72]

Insight

AgroCares launched a Near InfraRed (NIR) soil scanner in Kenya, giving farmers real-time information on the nutrient status of their soil. This on-the-spot soil testing benefits farmers by making soil testing fast, affordable and productive. It also benefits farmer cooperative's by making soil testing services a business.

Case study — **Kenya**

How it works

- The hand-held scanner sends a spectral image to the application on the smartphone via Bluetooth
- Subsequently, the smartphone application connects to AgroCares' global calibration database to convert the spectral image into the required soil data
- Interpretation of this data is dependent on the selected application - there are applications for monitoring (only data presentation), **liming recommendation** and several fertilizer recommendation applications
- The most used application is the 'Advisor application', which translates the soil data within 10 minutes into direct fertilizer recommendations for farmers for the selected crops
- The sensors can make around 30 soil samples per day

Investments

- The service provider buys the scanner for 3,000 Euro and a license for a specific application *(listed above)*. For example, the 'advisor application' costs 1,800 Euro per year with unlimited use of the database
- The cooperatives offer soil testing services to their members with a fee of approximately 5 to 8 Euros per report

Impact

- The 'Advisor Application' is now used by 37 organizations across Kenya, 20% of which are farmers cooperatives, operating 97 scanners
- Cooperatives achieve breakeven point within one year of purchase
- **For farmers, cost of scan is compensated by (i) reduced input expenses due to increased efficiency, and (ii) increased yields and higher return of investment**

The prioritization initiative requires a significant increase in the adoption, which in turn depends on awareness initiatives by the government, development partners, and other private actors such as agro-dealers.

- RAB and Rwanda Agriculture and Livestock Inspection and Certification Services (RALIS) have the public mandate to set regulations around inputs; thus, they would spearhead prioritization efforts e.g., their mandate could extend to putting soil testing regulations in place
- CIMMYT – an implementing partner of the GAIA project - and AGRA have previously (and plan to) support public institutions in Rwanda with research on soil acidity. CIMMYT is looking to support RAB in understanding lime application quantities while AGRA has already provided technical expertise to develop policies around lime use, application, and distribution. CIMMYT and partners would be well-positioned to provide input on other research endeavors.

2. Emphasize the 'how' alongside 'why' in sensitization programming

While there are ongoing efforts to increase awareness and generate demand, there is room for improvement. The current efforts aimed to increase lime uptake typically focus on the 'why' – the potential benefits of applying lime as a soil acidity solution. Communication needs to be targeted and cover the key gaps in farmer awareness, including best practices for lime application, access to financing of lime, and exacting yield estimates that can be expected with the proper application all year-long:

- **Application techniques should better explain current and best practices.** For instance, under the micro-dosing/spot application, lime is applied at the specific point of planting, whereas banding is where lime is applied in bands where crops are cultivated.

[72] Source: ICT Update Issue 89, Data4Ag: New Opportunities for Organized Smallholder Farmers, 2018

Development partners may opt and advocate for these practices. However, liming across the entire farm is believed to be the best practice. Farmers should understand the different options and make informed choices. [73]

- **Exacting yield estimates – as monitored and observed in similar soil types assuming proper application, will give farmers more realistic expectations**. Moreover, consider setting the right expectations, demand generating programs should provide forward information on the potential lag time for lime; lime can take up to 2 years to reach the desired pH (with initial rectification and subsequent maintenance applications) as opposed to other inputs. As a result, farmers need to understand that they may not immediately realize the benefits, as they would with fertilizers.
- **Given the cost and cash flow constraints of purchasing lime, financing will be a critical component of engagements with farmers**. This will entail navigating the cost breakdown, including purchase and transport costs, purchase timelines highlighting the first-year application and subsequent applications to maintain soil health, and financing options. With the new distribution model, farmers may require additional credit financing to purchase lime. In this case, it will be important to describe the varied options available: the government-subsidized lime requiring upfront payment, One Acre Fund's on-credit lime purchase where farmers pay 100% of the lime purchased, lending through farmer trusted entities such as farmer groups, etc.

To ensure the success of demand-focused sensitization efforts, it will be critical to engage the on-ground extension to (i) liaise farmers and their needs with lime suppliers; (ii) disseminate technical know-how for lime application; and (iii) support farmers with financing questions, etc. Demand generation is the most critical as demand and supply are inextricably intertwined, and it requires engagement from numerous stakeholders, including district offices, extension networks around Rwanda, and farmer groups.

AgriFin and government-associated agro-dealer networks, AGRA, RAB, and RALIS were a part of a coalition that previously rolled out demonstration plots to create an appetite for lime adoption. These actors' expertise would prove useful in scaling subsequent farmer outreach. Further, there are existing agro-dealer networks that can be leveraged in Rwanda such OAF's field officers, and AGRA's village-based advisors.

[73] Stakeholder engagement (CIMMYT)

Figure 16: AGRA case study on expanding extension networks[74]

Rationale

- AGRA has invested in VBAs to expand their extension networks; they have trained over 33,000 VBAs who serve nearly 4 million farmers over 4 years.

Intervention & Activities

- Through their key role of advising and training, VBAs also create demand for new technologies and products – applicable to the liming practice and lime
- The incentive for VBAs would be the promise to earn income by graduating to agrodealers. In AGRA's experience, nearly 27% and 22% of VBAs eventually start distributing fertilizers and agro-chemicals to fellow farmers

Impact

- Adoption of inputs within farmers that are supported by VBAs improves dramatically with VBA training. For instance, 17% and 5% of VBA supported farmers in Ghana and Rwanda adopted improved seeds before VBA training compared to 79% and 98% after training in the two countries respectively

Supply-side opportunities

In parallel, there is a need to improve the commercial viability of supplying lime at the required level of quality and cost. Given the identified supply-side binding constraints, these opportunities will center around developing processing capabilities to ensure high-quality lime products, provide last-mile delivery at reasonable transportation costs, as well as ensure long term supply of lime transportation costs and ensure

It would be helpful to understand whether current capacity constraints and the ability to scale to reduce cost could best be solved through a 'build, expand, or partner' approach. The opportunities presented here are biased towards building individual processors' capabilities (e.g., funding for processors) and partnering with other actors to reduce costs and address inefficiencies (e.g., deliver lime to nearer markets within the context of the government tender program, policy revisions). However, there may be underdeveloped opportunities around expanding – be it vertical or horizontal integration – to capture more value in the supply chain. For example, cement processors may adopt horizontal integration and produce agricultural lime, thereby reducing transportation costs as they have slightly better economies of scale and would use comparable distribution channels

[74] PIATA Impact Assessment, 2020

Improve processing capabilities to ensure high-quality liming

3. Earmark patient capital and leverage innovative financing mechanisms for supply chain actors

Given the unique financing challenges for different supply chain actors, opportunities to address access to finance also need to be specific.

- **Smallholder farmers.** There is a need for well-structured financing programs that are designed to work for farmers and address their cash flow constraints to ensure that they can afford to purchase lime promptly. Smallholder farmers will need input finance schemes e, g., credit product offerings through microfinance institutions (MFI), cooperative and saving societies (SACCO), or individual organizations such as One Acre Fund and Access to Finance Rwanda. It is important to leverage these alternative financial institutions for smallholder farmers; adults who report agriculture as their primary income report that their access to the formal financial sector is primarily through nonbanks—savings and credit cooperatives and mobile money providers.[75] Moreover, nearly half save with formal providers, but only one in ten borrows from formal providers. Nonbank financial products are structured in diverse ways including interest-free loans, digital platform loans, for example, MTN Mobile Money or SPARK[76] loans, and shorter due diligence periods loans backed by loan guarantees.

  There are also opportunities to bundle products offered to smallholder farmers. Bundling services ensures that farmers simultaneously have access to an array of complementary products and services as shown in the Safaricom case study in Figure 17

Figure 17: A case study of DigiFarm bundled products[77]

Safaricom Twaweza

Digi Farm is a collaboration between Safaricom and Mercy Corps where they built an integrated platform that bundles different services to support over 7 million smallholder farmers in Kenya

iProcure

DigiFarm partnered with iProcure, a farms input supply company which leverages eCommerce platform to offer discounted products to farmers

FarmDrive

DigiFarm also hosts FarmDrive, to provide agriculture loan products based on alternative credit scoring. Once farmers access loans, in minutes, they can use the loan code to purchase inputs

Arifu

Lastly DigiFarm is working with Arifu, a learning platform that offers informational content to farmers

[75] World Bank, Agriculture Finance Diagnostic, 2018
[76] SPARK, Lower interest rates and digital loans for Rwandan farmers, 2020
[77] Mercy Corps, AgriFin Digital Agriculture Platforms BluePrint, 2020

- **Processors:** The processor capability challenges point to financial constraints most prevalent at the production stage of the lime supply chain in Rwanda. With limited financing options, there are opportunities to expand the product offerings available to processors. On one hand, given the current low level of demand for lime in Rwanda, processors may require access to patient equity investments. On the other, there may be opportunities for traditional banks 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.

  To build their internal capacity, processors will need to articulate their investment needs. For example, smaller-scale players could approach financial service providers and donors to explore financing opportunities, including credit and grant offerings towards funding the technical know-how and the acquisition of equipment. Accountability and financial service providers' willingness to tailor their financial products will be critical to affording processors with access to tailored capital\;
    - **Accountability on the use of the patient capital and transparency on repayment plans are important**. This is particularly the case with financing options, including the backing of development partners at times misconstrued as free money. The lime supply chain in Rwanda would benefit from a culture of accountability[78]
    - **Availability of innovative financing schemes and funds that meet limestone processors' ticket sizes and risk appetite is critical.** For example, previously, funding institutions such as the Dutch Rabobank, Development Bank of Rwanda (BRD), and development partners such as USAID' Nguriza Nshore' have backed agriculture input manufacturers and suppliers.[79] Financial service providers will need to carefully consider and tailor the term/tenor of these financial products - taking into account the nascent nature of the lime sector, timelines for results and thus the expected adoption curve, the long-term investment nature for lime, etc.

- **Distributors:** While there are currently no glaring access to finance gaps at the distribution stage, there may be an increasing need for innovative financing for asset-heavy businesses to potentially expand their vehicle fleet or install on-site storage, to achieve economies of scale by transporting lime in large volumes. However, it is important to note that capital acquisition may increase financing obligations and increase already significant distribution costs. Thus, it is prudent to explore other opportunities before investing in storage and transportation facilities. For instance, an interviewed farmer group uses underutilized crop stock houses – previously finance by MINAGRI – to store lime.

- **Agro-dealer**: Like farmers and processors, agro-dealers will also leverage both traditional financial service providers and other channels to access financing – primarily in the form of short-term working capital or investments in storage capacity. Moreover, in terms of service provision to smallholder farmers. Equity Bank and KCB Bank Kenya exemplify tailored

[78] Stakeholder interviews (NGOs)
[79] World Bank and AgriFin, Input Supply Finance, 2017; Previous Dalberg engagements, 2019

financial solutions to enable agro-dealers to provide service to smallholder farmers. The banks identify high-performing agro-dealers to serve as agents that offer financial services to their farmer network – they typically reach out to agro-dealers with nearly 10X the average size of other agro-dealers' networks. The Equity and KCB banks programming extends preferential loan terms to farmers through agro-dealers and provides agro-dealers with a host of other services such as business development and financial training.[80]

Improve last-mile delivery at reduced transport costs

4. Leverage supply routes, on-ground facilities, vertical integration, and technology to facilitate farmers' physical access to lime

Farmers incur additional costs in transporting lime from often far-off drop-off points. There are opportunities to (i) modify drop-off sites – shifting to sites closer to smallholder farmers; (ii) leverage technology to record and fulfill orders directly to farmers; (iii) vertical integration; and (iv) explore asset sharing to improve storage facilities to ensure last-mile delivery to farmers in a time-effective manner.

- **Modify drop-off sites.** One Acre Fund is cited as being better with last-mile delivery than the public-backed distribution model primarily due to their drop-off sites- publicly commissioned suppliers deliver lime at district offices, while One Acre Fund typically delivers inputs at the sector level.[81] RAB and MINAGRI could explore additional costs incurred to deliver lime at drop-off sites nearer to farmers. For example, understanding the additional cost of transporting lime to sector level offices rather than district level officers and exploring options to subsidize and/or finance last-mile delivery.
- **Leverage technology to record and fulfill orders directly to farmers.** Digital platform can improve the rate at which inputs reach remote communities – at the right quantities, right quality, and at the right time. For example, the government-backed Smart Nkunganire input distribution system and the FarmerLine platform enables farmers to place orders for agricultural inputs via a USSD platform on their mobile phones.[82] Using digital platforms provides a schedule of farmer orders so that (i) agro-dealers can plan to deploy other 'drop-off point to farmer' transportation; and (ii) enables farmers to plan the transport from the drop off point to their farms, in advance.
- **Vertical integration of processors to distribution:** Lime processors state that vertical integration would help them capture more value in the supply chain and reduce costs incurred in distribution.[83] A study on input distribution across different African countries demonstrates that, in Tanzania, fertilizer manufactures could reduce cost by 10 – 15% if they were to invest in direct distribution.[84] 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.
- **Asset sharing and partnerships with other input companies:** Some input providers such as One Acre Fund have managed to establish last-mile temporary storage facilities through utilizing schools and churches.[85] There are opportunities to collaborate with other input

[80] Goedde et al, Winning in Africa's agricultural market, 2019
[81] Notes: Rwanda has 30 districts further subdivided in 416 sectors; Source: Stakeholder interviews (NGOs)
[82] Farmer line, How legwork supports the delivery of technology solutions to the agricultural last mile, 2021
[83] Stakeholder interviews (lime processors)
[84] Goedde et al, Winning in Africa's agricultural market, 2019
[85] One Acre Fund Blog, Providing-last-mile-delivery-farmers-across-sub-saharan-africa

companies such as seed and fertilizer manufacturers of distributors and share distribution costs, and warehousing. Example initiatives include The Last Mile Alliance in Tanzania, which was a partnership of Bayer – a fertilizer manufacturer, NMB Bank, and seed companies such as Seed Co, Syngenta, and Yara. Together, they worked to establish agro-dealers who would help in training and demonstration plots and use of defunct shipping containers to store inputs closer to farmers. It should be noted that there are volume discrepancies between lime and other inputs (seeds and fertilizers) which tend to be compact. Thus, models to share distribution assets may only work for blended products, for example, lime blended with fertilizer, rather than lime as a distinct product. Importantly, the engagement of other actors is likely to be contingent on scaling demand for lime. As an example, Figure 18 outlines the challenges of attracting cement processors.

Figure 18: Brief synthesis on the potential to engage cement distributors into agriculture in Rwanda

Case study: Why cement processors are less likely to distribute agriculture lime at this stage[86]

- Cement producers in Rwanda such as CIMERWA own their quarries and process their lime – a principal raw material for cement
- While the quality of agriculture lime is ascertained through its chemical and physical properties, quality assessment on construction lime focuses on the chemical composition of the product; for instance, there is a threshold for MgO and beyond which the quality deteriorates. There are similar processes in manufacturing both limes; however, the processing requires different equipment distinct capital expenditure line items. For instance, the kiln has different temperature ranges, fineness, and thus, the mesh sizes vary – cement lime is measured in microns while agriculture lime typically uses the 25 mm seave
- Cement processors have far-reaching distribution networks that can be leverage for ag lime distribution
  - However, only an unmet demand would warrant cement processors venturing into ag lime production
  - Rwanda neither has the unmet demand, and cement lime is nearly 15X more valuable than agriculture lime; engaging cement producers in the distribution of ag lime is a tall order

5. Embed proximity to demand into the selection criterion framework

Given the significant share of district offices in the lime demand in Rwanda, **RAB can embed 'limestone deposit proximity to the districts in question', as a criterion for selection, to minimize transport costs**. This is a viable opportunity as different processors are scattered around Rwanda's Northern, Western, and Southwest regions with higher soil acidity prevalence. The monthly capacity of small-scale processors ranges from 450 MT – 15MT/day to 2000 MT monthly. Given that district, demand ranges from 1,.000 to 4000 MT, and the new processor requirements are 10,000 MT, most processors will have to scale up to meet processing requirements by public stakeholders and cover more than two districts.[87] As a result, lime supplier contracts can be awarded based on proximity, to reduce transport costs.

Buy-in from public sector, better inspection procedures, and evidence support will be critical to the proposed initiative. The current selection framework for lime suppliers is primarily focused on quality and end price of lime. Ideally, the selection framework should be revised to give preference to suppliers who are closer to farmers they intend to serve lime to reduce transport

[86] Stakeholder interviews (cement company and lime processors)
[87] Stakeholder interviews (lime processors)

costs. For example, the case of Homa Lime (Figure 19) demonstrates that processors incur additional costs when lime is transported to further distances.

Figure 19: Homa Lime Co. Ltd as an illustration of additional costs incurred delivering lime to further distances[88]

Homa Lime Co. Ltd

Rationale

- Homa Lime is a lime manufacturer based in Kisumu, Kenya. They started operations in 1920 and engage in limestone quarrying and processing as part of their diverse portfolio of revenue earning activities
- An assessment of their point-of-sale costs indicate that lime cost increased based on distance from manufacturer due to high costs of transport

	Point of sale price	Distance from factory (km)
Factory Gate Price $42/MT	Kisumu – plus $1/MT	~71
	Eldoret – plus $15/MT	~110
	Kisii – plus $17/MT	~130
	Kitale – plus $22/MT	~180
	Thika – plus $32/MT	~280

Considering Kisumu – the factory's hometown as the outlier, the average **price of lime increases by ~ $0.12 per tonne for every extra kilometer** the lime is transported from the factory

Further, MINAGRI and RAB will need to efficiently conduct quality inspections as district offices are no longer responsible for quality compliance.

Ensure lime supply in the long term

6. Ensuring efficient lime use while engaging neighboring countries in the lime supply chain

Rwandan lime supply chain actors should increasingly look for opportunities to complement local production with imports. Despite concerns on depletion of lime resources, addressing sustainability of supply is not yet part of the lime discourse. There may be opportunities for the Rwandan lime supply chain to make the available stock last longer as well as tap into other countries' unique advantages to further build the domestic lime sector. For instance, Burundi has companies such as the fertilizer producer Formiq with good lime processing equipment and expertise, while DRC has extensive lime deposits in North Kivu, including Kasugho, southwest of Lubero, and in Katana.[89] Figure 20 shows how other countries in the region, notably Kenya, rely on imports, to complement their locally-sourced limestone, albeit for premium lime products.

[88] Stakeholder interview (Kenya field visit)
[89] IFDC, Solving Agricultural Problems Related to Soil Acidity in Central Africa's Great lakes Region, 2008

Figure 20: Kenya as an illustration on lime imports[90]

Rationale

- Kenya, the more commercial lime value chain in the region, leverages imported lime to complement local production The import channel provides granulated lime – not widely available in the country, to cater for a more high-end clientele

Imported lime in Kenya

- While local production can effectively supply powdered lime, importers typically engage in granulated lime which is **6X more expensive than powdered lime** at a final price of $720/MT
- Importing granulated lime at a high price point implies clientele segmentation where granulated lime is **reserved for large and medium farmers especially those engaging in high-value crops** such as horticulture crops to export to destination markets with high quality and quantity requirements
- Furthermore, in-country lime suppliers use **granulated lime within fertilizer blends** to work around the affordability issues and simultaneously leverage the same distribution channels for fertilizers – which is more widely adopted by farmers across the country

Understanding the lifespan of the lime deposits will help supply chain actors ensure their efficient use. From our initial analysis, we estimate that the lifespan of the available limestone – accounting for lime required for soil rectification and maintaining annual health, to be~16 years. However, these calculations are based on lime deposit data dating back to 2001[91], and quantifying the lifespan of Rwandan ag lime will require updated information on deposits. With an accurate understanding of the lime reserves available, stakeholders can prioritize target areas (for example, based on pH levels, foregone yield, and ease of distributing lime) and ensure that current limestone deposits' are used effectively and efficiently.

In parallel, 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. Stakeholders such as the Ministry of Foreign Affairs and Rwanda Mines, Petroleum and Gas Board (RMB) can (i) articulate value proposition for both countries; (ii) delineate guidelines for government and private sectors to engage in cross-border lime trade relations; and (iii) facilitate linkages between public and private sector actors, such as lime suppliers, to allow for technical expertise exchange and lime trade.

In seeking to address supply chain challenges, it is important to note that without demand, there is likely to be limited uptake of any opportunity to these gaps. For example, extending patient capital to processors depends greatly on the strength of the lime sector and the investment seekers' links into the industry. Strong demand will introduce opportunities to reduce default risk and borrow against their assets. Our analysis points to the need to increase demand as the most important factor to unlock growth in the sector.

[90] Stakeholder interviews (Kenya lime processors)
[91] SOFRECO (2001). Evaluation and classification of travertines deposits. Kigali, Rwanda: Ministry of Industries and tourism.

Enabling environment opportunities

7. Set standards around appropriate lime use and application as well adopt a phased approach to implementing the processor requirements

Identifying appropriate pathways towards commercial viability will also require an analysis of access to finance and policy gaps. The policy and finance gaps are most pertinent at the processor and farmer lime application stage.

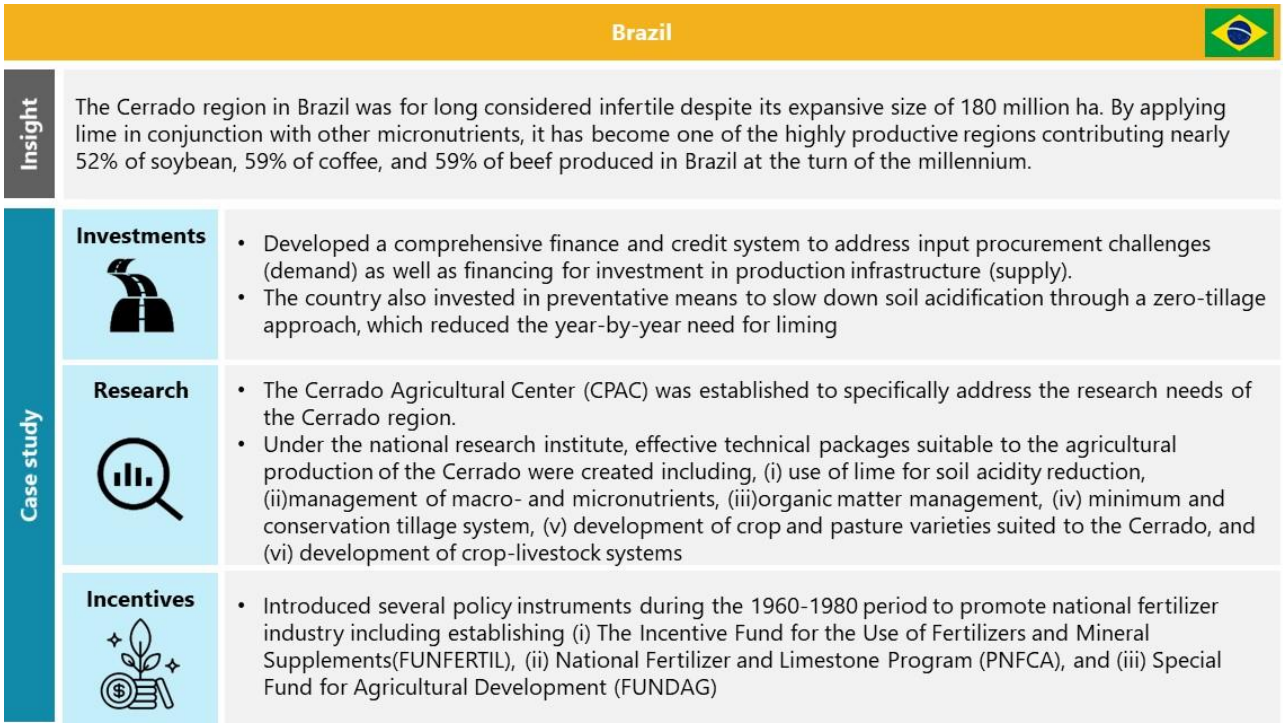
- **Processors:** Processing requirements in the new distribution model may undermine the sector's commercial viability if not addressed promptly. The requirements stipulate the need for 10,000 MT storage and packaging, a far cry from processors' actual capabilities in Rwanda. Rather, processors may need a ramp-up period – to scale up to the capacity required and the operating costs, e.g., for laminated bags. RAB and MINAGRI can examine a set of revisions to the current requirements, such as increasing the frequency of RAB quality inspections which would assess quality, for instance, after 500 – 1000MT batch production instead of drawing from a sample with 10,000 MT storage for an agreed-upon period.
- **Lime application:** 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.[92] However, similar standards do not 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 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 at the farmer level.[93]

8. Engage the private sector to further strengthen the lime supply chain and the environment

A coordinated government effort that prioritizes soil acidity as a critical issue and a collective effort with other stakeholders is key to creating a strong enabling environment for lime. Beyond the challenges laid out, governments will need to work with other stakeholders to put in place the appropriate investments, fiscal incentives such as feed and tax breaks, as well as quality standardizations. For example, as shown in Figure 19, similar efforts in Brazil have turned the country's most infertile land – the Cerrado region - into its breadbasket.

[92] RSB support towards food safety presentation by the National Certification Division, 2015
[93] Stakeholder interviews (NGO_

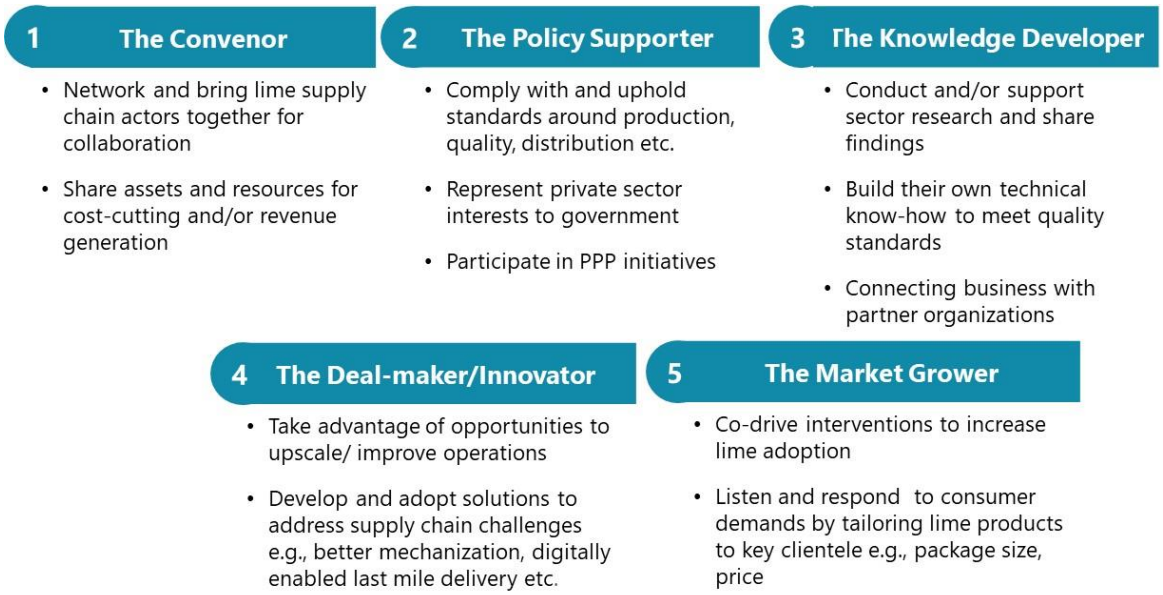
Figure 21: A case study on Cerrado region (Brazil)[94]



Beyond the government, there are opportunities to engage private sectors' involvement in the implementation of recommendations and further strengthening the supply chain by addressing persisting challenges. As shown in Figure 20, we envision the private sector playing five distinct roles- convener, policy supporter, knowledge developer, innovator, and market grower.

[94] Source: Infrastructure and Conservation Policy in Brazil; Land-use trends and environmental governance policies in Brazil; The Economist: Miracle of the Cerrado; Ethiopian Agricultural Transformation Agency (ATA), 2016

Figure 20: Roles of the private sector



- **Convenors:** Private sector has arguably the most critical role in shaping thought leadership and advising/influencing government and development partners. It will be critical to convene private actors to develop a common voice and share resources. Private actors are well placed to:
    - Create a forum of different stakeholders
    - Develop lime supply chain member directories, and develop periodic newsletters to share information on the subsector
    - Facilitate connections between stakeholders with a vested interests in addressing soil acidity
- **Policy Supporter:** Policies and interventions developed by the government are either directed to or executed by the private sector. The public sector is reliant on the private sector to:
    - Comply with regulations
    - Provide input on improving the enabling environment given their strong understanding of how these regulations play out on the ground
    - Collaborate with the public sector to launch public-driven initiatives; for example, national subsidized distribution of lime
- **Knowledge developer:** Given the information gaps, this is a critical role that has been previously played by development partners and that private actors can increasingly contribute to. For instance:
    - Spearheading efforts, in collaboration with research institutes, to test for additional lime deposits
    - Measurement and tracking of yield improvements
    - Facilitate shared learnings with a diverse set of stakeholders
- **Innovators:** There are an increasing number of innovations in the agriculture sector, in the region, which can support the growth of lime supply in Rwanda. For example,
    - Digital solutions that streamline distribution; for example, iProcure, business intelligence and data-driven stock-management company used by input

distributors or use of geo-mapping software to optimize supply routes for distributors[95]
    - Develop partnership terms to provide additional incentives. For example, moving incentives towards volume-based discounts, establishing special prices for cross-selling input distributors to incentivize seed and fertilizer distributors' adoption and sale of lime using their distribution channels.
- **Market grower:** Creating demand should not be reserved for the public sector and development partners. Indeed, private sector actors have the vested interest and capabilities to drive the demand of lime. For example,
    - Processors can leverage an increasingly digital environment in Rwanda – such as the online input voucher system and its accompanying phone services– to disseminate information and drive demand
    - Provide technical support to run demonstration projects effectively and ensure that the results are efficiently tracked, validated and disseminated.
    - Leverage supplier networks to forge trade relations with lime providers in neighboring countries.

The GAIA project is well placed to guide and manage the lime ecosystem and to generate the knowledge required. The project plays a central role as a technical expert on soil acidity, where the institution has undertaken several studies around the subject and specifically the liming practice in focus countries, including Rwanda. Further, the GAIA project has forged strong relationships with in-country public or private implementing partners. This positions the institution as a potential liaison between the external ecosystem and the in-country lime stakeholders who can facilitate the exchange of information, technical expertise as well as financial support.

Figure 22: Potential risks linked to rolling out recommended initiatives

Intervention	Potential risks	Proposed mitigation strategies
Focus interventions on high-impact areas	Misalignment with other stakeholders such as district offices on the extent of lime access support	• Ensure public dissemination, transparency, and evidence support on the prioritization scheme, its evidence-based results as well its implementation plan
Emphasize the 'how' alongside 'why' in sensitization programming	• Overburdening existing extension services agents' different regions • Elaborate and time-consuming information sessions for smallholder farmers	• Bundle training with other inputs' demonstration and awareness campaigns to work around extension agents and farmers' time poverty • Engage input application specialists to identify critical information to disseminate and build information packs/sessions to cover the most critical and 'must-know aspects concisely

[95] Reach Alliance, Reaching the Last Mile: Tanzania's Medical Supply Chain, 2019

Earmark patient capital and leverage innovative financing schemes for supply chain actors	Financial institutions' limited expertise in designing tailored financial products for the agriculture-focused mining activities and lime sector	• Avail technical assistants and advisory personnel for financial institutions and involved development actors
Leverage supply routes, on-ground facilities, vertical integration, and technology to facilitate farmers' physical access to lime	Last-mile delivery could require prohibitively high additional costs that translate into an increase in end-consumer prices	• Develop minim viable products and/or prototypes for last miles delivery solutions and track performance/success • Model last-mile delivery at different lime volumes and schedule last-mile delivery interventions with increased demand and larger volumes transported
Ensuring efficient lime use while engaging neighboring countries in the lime supply chain	• Neighboring countries and private sectors' unwillingness to engage in lime trade • High cross-border trade costs and difficult quality assurance procedures	• Leverage lime excavation and research expertise to explore undiscovered lime deposits • Negotiate favorable import/export agreements applicable to agriculture inputs and incapacitate close to border quality assurance capabilities
Set policies around lime use, and application and adopt a phased approach to achieving processing requirements	• Delayed policy implementation and/or policy changes	• Identify champions in public institutions • Leverage technical assistance to illustrate the need for policy additions/changes; high evidence base has proven to increase the pace of guideline/policy reform

IV. NEXT STEPS

This study focused on identifying the key challenges in the supply side and identify opportunities to address the challenges. This supply chain assessment illustrates that the lack of demand is the critical binding constraint to the supply of lime in Rwanda, where demand, supply, and enabling environment are strongly interlinked.

As a first step, we recommend that stakeholders discuss and align on the outputs of all work packages. Besides our work package, GAIA has commissioned different work packages focuses on i) alternative investments in soil acidity, ii) incentives to adopt soil management, iii) knowledge gaps on the impact of lime, iv) policies to support investment, v) multistakeholder collaboration, vi) access and use of data, etc. Consolidating output from these work packages will be the aim of the national investment plan, with a draft to be delivered in the first quarter of 2022 and by engaging with different work packages, the involved teams will ensure an adequate understanding of the core challenges and interlinkages between demand, supply, and policy. This will enable stakeholders to align and collaborate and develop tailored solutions. This is the first step to understanding the building blocks of a national investment plan.

There is a need to build commitment to increase resource allocations to the agriculture sector recognizing its importance. Despite resource constraints, the government of Rwanda has shown commendable commitment to addressing soil acidity. The Government of Rwanda and other on-the-ground partners should sustain the momentum to improve demand and supply (capacity-building etc.) so that liming can deliver clear results and outcomes, particularly at the farmer level.

As noted in this report, this requires supportive policies, informed by a diagnosis of the current situation and relevant financing mechanisms to enable private sector investment to achieve sustainability and growth in the sector. Based on our findings on the supply side, the specific technical areas for consideration as part of a national investment plan to achieve growth of liming in Rwanda include:

- **An evidence-based approach** to inform interventions and government priorities when it comes to addressing soil acidity. This implies relying heavily on research to, for example, understand the soil acidity levels with frequent sample testing, assess limestone deposits for future planning, research lime quantities required with different soil types, etc.
- **Strengthening govt capacity** to provide relevant, market-oriented agricultural extension services to support awareness programming as well as ensure last-mile delivery. Farmers' skepticism on yield improvements – borne out of misinformation or lack of information, as well as the additional burden of transporting lime from the far-off drop-off point, are two of the main demand deterrents for Rwandan smallholder farmers.
- **Stakeholder coordination**- effective mechanisms for multi-sectoral and multistakeholder coordination, support program implementation, and M&E. This is particularly critical at this juncture where government stakeholders are launching the new distribution model
    - *Quick win adjustments* to further refine the policy and regulatory environment. This may include, for instance, updates to the lime supplier requirements, at the discretion of RAB/MINAGRI,

    - *Long-term initiatives* focused on addressing supply actors' capacity gaps and access to high-quality lime. For instance, cross-border trade of lime will include coordination between government stakeholders, border authority, and lime suppliers from different countries, as well as necessary alignment on lime standards

- **Improved access to agricultural finance and investments** to improve lime i) processing capabilities by ensuring use of mechanization services, technical know-how on quality lime production and delivery at reasonable costs, and ii) access by farmers given cash flow constraints.

V. ANNEX

List of stakeholder consultations informing this report

1	Rwanda Agriculture Board
2	Rwanda Agriculture Board
3	IFDC
4	One acre Fund
5	One Acre Fund
6	AGRA
7	ALICOMEC
8	COCHAUMA
9	SOPAV
10	CIMERWA
11	Nasho Irrigation Farm
12	Gwiza Cooperative

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